SKYLAB EXPERIMENT OVERVIEW

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PREPARED BY BELLCOMM, INC
FOR THE SKYLAB PROGRAM OFFICE

PREFACE

The intent of this document is to provide a current description of the Skylab Experiment Program to a level of detail adequate for a general understanding of program rationale and experiment operation. The major research areas of Medical Sciences, Solar Physics, Earth Observations, Astrophysics, and Engineering and Technology are outlined, relating disciplinary goals and past accomplishments to the Skylab Experiment Program. Appended to these overall disciplinary chapters are descriptions of the individual experiments, including experiment objectives, relation to discipline, hardware description, and operational protocol.

Every effort has been made to provide information which is accurate and current as of January 1, 1971; however, in some areas changes are occurring very rapidly.

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CHAPTER ONE

THE SKYLAB EXPERIMENT PROGRAM

INTRODUCTION*

The Skylab Program capitalizes on the capabilities and resources developed in the Apollo Program to accomplish scientific, technological and biomedical investigations in space. The Skylab Program has been initiated with the goal of achieving a series of steps leading toward the establishment of an operational capability in earth orbit. This capability will result in expanding the scientific knowledge of our earth and the surrounding universe. In addition, Skylab will build the foundation for future major steps in manned exploration beyond the earth-moon system.

The basic objectives of the Skylab Program are described as follows:

Scientific Investigations in Earth Orbit - Scientific investigations are a significant portion of the Skylab missions. The information received from these scientific experiments will substantially increase man's knowledge of the sun and bring closer the day when he can understand the remarkable physical phenomena evident there and the effect of these phenomena on man's existence on earth. Astronomical and space physics experiments will be conducted in addition to several biological experiments. Advances in knowledge concerning the universe, the space environment and the phenomena that exist in the solar system and the effect of the environment of man on earth are foreseen.

Applications in Earth Orbit - Skylab experiments for earth resources study will use remote sensing techniques to gather data for use by experts studying oceanography, water management, agriculture, forestry, geology, geography and ecology. The orbital path of Skylab flights will permit earth resources survey coverage of the entire contiguous United States and much of the world.

Long Duration Space Flights of Men and Systems - The unique capabilities of man as a participant in space flight

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*The material in the introduction and mission sections of this chapter is taken largely from "Skylab Program Technical Summary", OMSF-NASA, June 1970.

activities will be evaluated. Habitability, biomedical, behavioral and work effectiveness experiments will be performed. The life of systems and subsystems of space vehicles will be measured by techniques developed in Skylab flights.

In the first Skylab flight the effects of prolonged weightlessness on man's health and behavior will be investigated as well as his ability to carry out his various duties. This first mission will last up to 28 days or twice the duration of existing experience. The second and third Skylab flights are planned to last up to 56 days.

Effective Economical Approach to Development of a Basis for Potential Future Space Programs - Skylab missions will provide the development of the capability for man to operate in space for increasingly longer periods of time. The basis for future long-duration space station design and development will be explored and evaluated on these missions.

MISSIONS

One Saturn V flight and three Saturn IB flights are scheduled for the Skylab Workshop (SWS) mission. The first segment of the mission will be insertion of the SWS into a 235 nautical mile earth orbit, using the Saturn V. This segment will provide an unmanned ground-outfitted S-IVB stage for future use as an orbital workshop to conduct inflight experiments in science, technology, engineering, medicine, and solar observation. The three S-IB flights will provide a manned Command and Service Module (CSM) to form an orbital assembly with the SWS. These manned missions will demonstrate rendezvous, resupply, and orbital assembly techniques; will investigate man's ability to withstand space environment for periods in excess of those achieved in the Gemini Program; and will gather scientific data about the earth and the solar system.

Mission Profiles - The first mission, SL-1/SL-2, will consist of two launches approximately 1 day apart. The SL-1 unmanned configuration will consist of a two-stage Saturn V launch vehicle and an SWS comprising a modified S-IVB orbital workshop, airlock module, multiple docking adapter, Apollo Telescope Mount, instrument unit, and the fixed part of the payload shroud.

Before launching the SL-2 CSM the SWS will be checked by ground command and telemetry data for suitable operational condition to justify launching of SL-2. The SL-2 manned CSM will be launched by a Saturn IB vehicle. The flight azimuth and launch time will be prescribed by the rendezvous flight plan.

The CSM will be inserted into an 81 x 120 NM phasing orbit. The SM service propulsion system and the service module reaction control system will then be used to complete height, orbit-plane-phase, and CSM rendezvous maneuvers and to dock with the SWS.

The SL-1/SL-2 mission will be primarily directed toward the accomplishment of a series of medical experiments related to the extension of manned space flight. Secondary emphasis is on solar astronomy, earth-resources, and technology experiments. This mission will be open-ended, but is planned to last 28 days, beginning with the launch of the SL-2 CSM.

The SL-3 manned CSM revisit mission will be launched by a Saturn IB vehicle from KSC. The SL-3 launch will be approximately 70-90 days (as dictated by launch pad turn-around time) after the SL-2 launch. The SL-3 mission will be open-ended, but is planned for a duration of up to 56 days from launch. The mission will be to resupply the SWS and to further exploit the medical, technology, scientific, and earth-resources experiments, with major emphasis on the solar astronomy experiments.

The SL-4 manned CSM revisit mission will be launched on a Saturn IB vehicle from KSC approximately 90 days after the SL-3 launch. Like the previous revisit, this mission will be open-ended, but is planned for a duration of up to 56 days from launch. The SL-4 mission will be to resupply the SWS and complete technical and scientific experiments. Major mission emphasis will be placed on the earth resources experiments.

EXPERIMENTS

The skylab experiment program consists of approximately 50 technology, and biomedical experiments. The SWS houses a number of the experiments, and also carries several large externally mounted experiments. There are two scientific airlocks, which provide the capability for the astronauts to put small scientific instruments "out the window" into the vacuum of space.

The major experiment areas are:

- Biomedical Sciences, which consists of 13 flight experiments dealing with the long-duration effects of space on men and animals. This area also includes a number of ground-based pre- and post-flight experiments

- Earth Observations, which consists of 5 flight experiments (Earth Resources Experiment Package, EREP) designed to study the earth from space.
- Solar Physics, which consists of 6 flight experiments, 5 of which are on the Apollo Telescope Mount (ATM).
- Astrophysics, which consists of 7 flight experiments designed to study the solar system and beyond.
- Engineering and Technology, which consists of 15 experiments which deal with the various unique properties of the space environment.

These experiments are discussed in detail in the following chapters.

CHAPTER TWO

MEDICAL SCIENCES

EXPERIMENT PROGRAM BACKGROUND

Rationale

From the beginning of manned space flight, there has been a continuing controversy about whether man can live and efficiently perform under space flight conditions. The controversy can be attributed partly to concern for the adequacy of the life support systems for man. This area of concern must be considered as an inherent part of each mission. The remaining portion of the controversy concerns the ability of man, as a living organism, to adjust to the spaceflight environment, and to readjust to the earth environment upon return.

The controversy has continued throughout the first decade of manned space flight because the missions through Apollo have been dedicated to single flight goals that overrode any concentrated effort to obtain detailed biomedical data.

Before NASA can embark on major manned programs of exploration and orbital operations, man's viability and usefulness in space must be assured. This can only be done through a careful quantitative study of man's physiological, psychological, and social adjustments as they occur in flight. Measures for the overall status of the crew at a given time during flight must be established, and an accurate time profile of the adaptation of men to space conditions must be developed. We must find out whether the long-term adjustments a man makes in space eventually lead to a new stable level, or whether continual adjustments cause him to eventually exceed his reserve capacity for meeting stress. Even if man does successfully adapt to space conditions, the return to earth involves an additional adaptive change which we know very little about.

The Skylab Program offers the first opportunity to study these questions in depth. The 28 and 56-day missions are long enough to study acute effects which could threaten man's safety as well as to observe slower biological processes. The biomedical experiments for the Skylab Program have been designed to study the suspected changes and to understand their basic mechanisms. The investigations are not conceived as medical monitoring procedures. The latter function will be performed operationally by known and fully tried bio-instrumentation and medical techniques and procedures.

The Skylab medical program is an intensive study of normal, healthy men and their reactions to the numerous stresses of space flight. Seldom has such a comprehensive examination been performed in ground-based studies, and never under the unusual stresses of prolonged space flight. A substantial gain in fundamental knowledge about human physiology is anticipated. In addition, by preparing for and conducting these multi-man extended missions, advances in earth-based medical applications in such areas as non-invasive bio-sensors, continuous long term monitoring of physiological processes and bio-telemetry will have a significant impact on medical diagnosis and treatment.

History

A basic set of biomedical data has been collected as a safety monitoring procedure on all the manned flights of the Mercury, Gemini, and Apollo programs. The parameters recorded have been heart rate, respiration rate, body temperature and blood pressure. These were supplemented by a variety of pre- and postflight measurements of such factors as exercise capability, cardiovascular response, hematology-biochemistry factors, immunology studies, and microbiological evaluations. In the Gemini program, medical experiments were conducted in flight to investigate the time course of the changes which had been noticed before and after previous missions.

Taken as a whole, these observations have generated the following picture of the physiological effects of space flight on man:

1) A consistent loss of body fluid.

2) A small but repeated loss in bone calcium and muscle mass.

3) A reduction in the ability of blood vessels to actively distribute blood to proper parts of the body in response to gravity - imposed shifts in fluid.

These effects completely reversed themselves within a few days after return to earth and so far have shown no consistent relation to flight duration (up to 14 days). However, there remains some concern that continued effects in extended missions could significantly reduce man's effectiveness in space and increase the danger of re-adapting to the gravity conditions on earth.

ROLE OF SKYLAB

Each manned mission in the United States space program was built upon the cumulative experience of preceding flights. Skylab will fly more men, in a larger spacecraft, with more varied activities, and for longer times than any previous American or Russian flight. It will provide the test conditions under which the biomedical effects observed to date can be studied more extensively than has previously been possible.

The Skylab biomedical program consists of three parts, each designed for separate purposes:

1) The actual stay of three men in space, with the associated operational medical monitoring and the observations of crew performance in a wide variety of scientific and operational tasks. This is designed to verify our expectations that man can perform safely and effectively in space.

2) The medical experiments are designed to investigate in depth the physiological and behavioral problems which have shown up in previous flights. Their results will provide greater understanding of the factors currently believed to limit the useful duration of man's stay in space.

3) The biology experiments are designed to study fundamental biological processes in the weightless environment which might ultimately be the factors limiting the survival time of any animal in space.

The knowledge and experience gained from all three parts of the program will be used to establish criteria for incremental increases in the duration of manned missions after the 28 and 56-day Skylab flights.

Three nutrition and musculoskeletal experiments have been designed to investigate the extent of skeletal and muscular alterations, and to evaluate biochemical changes and nutritive requirements. These investigations will measure input and output of fluid and biochemical constituents (Appendix 1), make X-ray estimates of bone demineralization (Appendix 2), and assess hormones and electrolytes in body fluids (Appendix 3).

A cardiovascular study with a lower body negative pressure device (Appendix 5) will test the cardiovascular reflexes which regulate the regional distribution of blood through the body. This important measurement will help to determine the onset and progression of changes in these reflexes. The cardiovascular investigation also includes inflight vectorcardiograms (Appendix 6) during exercise on a bicycle ergometer, in order to evaluate the response of the cardiovascular system to calibrated workloads in weightlessness.

Pre- and postflight investigations in hematology and immunology (Appendices 7-10) will investigate the effects of space flight on the blood cells, body fluid compartments, the hemostatis mechanism, body immunity, and chromosomal aberrations.

A neurophysiology investigation will evaluate several nervous systems responses. A human vestibular experiment (Appendix 11) will investigate the effects of weightlessness on man's perception of body orientation in space and will test for changes in sensitivity and susceptibility to rotation in weightlessness.

A second experiment in this area, sleep monitoring (Appendix 12), will investigate the effects of the spaceflight environment on sleep state patterns derived from an analysis of electroencephalographic (brain wave) and electrooculographic (eye movement) data.

A time and motion study (Appendix 13) will evaluate the relative differences and consistencies between ground and inflight task performance by comparing moving picture sequences of inflight activities with similar ground-based activities.

Energy expenditures (Appendix 14) will be measured by comparing the metabolic rate observed during rest with that found during the bicycle ergometer exercise.

To provide supporting information to these experiments, man and materials will be "weighed" in zero-g with two mass measurement devices of appropriate range (Appendices 4 and 15).

Circadian rhythm studies are concerned with the physiological periodicity of many body functions about the 24-hour terrestrial day/night cycle. In addition to obvious rhythms such as sleep and wakefulness, the endocrine, cardiovascular, nervous, and other systems and biochemical processes are influenced by this cyclic phenomenon. The influence of space flight on man's normal circadian rhythms will be evaluated from measurements of hormonal response, body temperature variations, heart rate, rest and activity cycles, and other data from the battery of medical and behavioral experiments on the flight crew.

A more fundamental investigation of the function of the biological clock which is believed to be responsible for the timing of these rhythms in man and other animals will be conducted by experiments with mice (Appendix 17) and vinegar gnats (Appendix 18). These experiments test the stability of the clock mechanism under space conditions and may provide some indication of its dependence on factors associated with the rotation of the earth.

In another biology experiment (Appendix 16), the biochemistry and microscopic structure of human cells in tissue culture will be examined during space flight by time-lapse photography and chemical treatment.

FUTURE DIRECTIONS

The 28 and 56-day Skylab flights will give us a good picture of man's adaptation to the space environment and his abilities to perform many operations in space. It will tell us whether there is any fundamental limitation in man's abilities in, and tolerance to, weightlessness for a 2-month stay in space.

Should limitations become evident from the results of the Skylab experiments, the basic information will have been obtained from which future experiments can be planned, the responses of flight crew in future missions can be predicted and preventive measures can be implemented. Such preventive measures may have limited effects on spacecraft design and program planning, such as different exercise methods, or special diets, or they may require radical design shifts in order to provide artificial gravity. Such a decision will have a major impact on the design and operating procedures for future orbital stations.

In addition to the information about man, our present approach to the design of long-term life support systems will be severely tested in Skylab, and the experience gained will be indispensible in the design of larger, longer duration systems.

APPENDIX I

Mineral Balance, Experiment M071

Principal Investigator: G. Donald Whedon, M.D., NIH

Development Center: MSC

Integration Center: MSFC

Contractor: None

Objectives

The objective of Experiment M071 is to determine the effects of space flight on the muscle and skeletal body systems by quantitative assessment of the gains and losses of biochemical constituents of metabolic importance. These constituents are Water, Calcium, Phosphorous, Magnesium, Sodium, Potassium, Nitrogen, Chromium, Urea, Hydroxyproline, Creatinine and Chloride.

Background

Continuous losses of calcium and nitrogen, such as those which occur in ground-based simulation studies, during long duration missions might result in impairment of skeletal and muscle integrity and the formation of kidney stones. Identification of the rates of actual deterioration will allow specific countermeasures to be taken on later flights such as the institution of exercise routines and the manipulation of dietary constituents.

The principal method of assessing the effect of a stressor on the biochemical integrity of the skeletal and muscular systems is to determine whether the stressor promotes a catabolic response which is greater than the anabolic capabilities of the tissues. The change in equilibrium may be reflected in an imbalance between the nutrient intake of the constituent in question and the output of it and/or its metabolites. A state of negative nitrogen or calcium balance is not itself detrimental unless it is of an extent and duration which results in compromise of the integrity of muscle or bone with resultant increases in susceptibility to disease or actual pathology. Prior to the onset of recognizable disease, however, minor changes in function can be demonstrated which will reflect later deterioration.

Bed rest immobilization studies have shown that in healthy young adults urinary calcium increases to 2-3 times the control level within 5 weeks after confinement. X-ray studies of the bones have demonstrated demineralization as soon as 2-3 weeks after immobilization. Gemini pre- and postflight X-rays have suggested a similar loss of mineral from peripheral bones; and the Gemini 7 mineral balance experiment has demonstrated a trend towards negative mineral banance. This experiment was not conclusive because of operational difficulties.

Hardware

The hardware to support M071 is supplied by other experiments. Crew body mass will be determined by the Body Mass Measuring Device supplied by Experiment M172. Unconsumed food remanents, feces and vomitus will be mass measured by the Specimen Mass Measurement Device supplied by Experiment M074. Facilities for collecting urine, feces and vomitus are supplied by the Waste Management System of the Habitability/Crew Quarters Experiment, M487. This experiment will also provide for urine sampling, specimen preservation (drying for feces and vomitus, and freezing for urine samples) and storage. In addition, M487 contains the food storage and preparation facilities including the water dispensing and measuring device.

Protocol

The experiment M071 will be accomplished in three phases: (1) Preflight, for days T-23 to T-2 consecutively, (2) Inflight, and (3) Postflight for 18 consecutive days, beginning immediately postflight. The functions to be performed and the controls to be exercised are:

A) Body weight (or mass) will be measured once daily immediately after the first urine voiding following the sleep period.

B) A standard diet of defined composition will be used since the composition of the crewman's diet must be known and carefully controlled. Preflight, each crewman will use this diet prior to the acquisition of baseline (or normal) data to allow the establishment of individual metabolic equilibrium. Every effort will be made to make the diet palatable.

C) Fluid can be taken as desired but all intake will be recorded. This includes fluid used for food reconstitution.

D) All urine, feces and vomitus will be collected pre- and postflight and preserved for analysis. Inflight, the amount of daily urine output from each crewman will be determined, and a measured, homogeneous sample of at least 120 milliliters (45 for M071 and 75 for M073) taken, frozen and stored for return as experiment data. All feces and vomitus passed will be collected, mass measured, dried and stored for return as experiment data.

E) Periodic blood samples pre- and postflight will be taken and the concentration of selected metabolic constituents determined.

Data Return

During the Skylab Program, three men will occupy the orbital workshop on three different occasions. The initial mission will last for up to 28 days and the other two for up to 56 days each. The Mineral Balance Experiment will occur on all three missions so that by the end of the Skylab Program, a continuous quantitative assessment of the muscle and skeletal body systems for nine different individuals will have been obtained. For each individual, a preflight baseline will be obtained followed by a day-by-day profile of his physiological reaction to the space environment and, postflight, his re-adaptation to earth normal conditions. Specifically, the following data on a daily basis will be obtained preflight, inflight and postflight:

1. Food consumption - nutritional and caloric content.

2. Fluid consumption.

3. Feces - mass and concentration of biochemical constituents specified in the Objectives.

4. Urine - total voids volume, and concentration of the biochemical constituents specified in the Objectives.

5. Vomitus - mass and concentration of the biochemical constituents specified in the Objectives.

6. Body mass.

In addition, blood samples will be taken periodically pre- and postflight and those parameters specified in the Objectives will be determined.

APPENDIX II

Bone Densitometry, Experiment M072*

Principal Investigator: Pauline Beery Mack, PhD., Texas Women's Hospital

Development Center: MSC

Integration Center: None

Contractor: None

Objectives

This experiment is designed to determine the occurrence of and extent of bone mineral changes in the crewmen by measuring the X-ray density of the heel and little finger before and after the Skylab flights.

Background

In both the Gemini and Apollo flights, the astronauts have lost a measurable amount of bone density, although the losses have been too small to appreciably weaken the bone. The loss has been generally greater in flight than in bed rest studies of comparable duration and comparable dietary calcium intake. For some unknown reason the loss in finger bone density of the flight crew is as much as to 20 times that of bed rest subjects, whereas the loss in heel bone density is about the same (within a factor of two) in the Gemini flights as in bed rest subjects. The losses do not increase with longer flights up to 14-day maximum duration which we have experienced thus far.

Hardware

The bone density is measured by the standard technique of irradiating the finger or heel with X-rays and measuring the photographic density of a film placed behind the limb. The film density is measured with a densitometer, whose output is electrically corrected for non-linearity of the film response to X-rays.

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*This experiment is currently under review, and may be changed in order to incorporate newer measurement techniques.

Protocol

X-rays of heel and finger bones are scheduled at the following times:

Pre-flight: 10 days, 48 hours, 4 hours

Post-flight: As soon as possible, 48 hours, 7 days, 40 days

Data Return

The data which is returned from this experiment will be readings of the bone density changes in the finger and heel of all nine members of the Skylab missions (three from the 28-day mission and six from the 56-day missions).

APPENDIX III

Bio-assay of Body Fluids, Experiment M073

Principal Investigator: Carolyn S. Leach, PhD., NASA, MSC

Development Center: MSC

Integration Center: MSFC

Contractor: None

Objectives

The objective of this experiment is to evaluate the endocrinological adaption resulting from exposure to the space flight environment for periods up to 56 days and to re-adaptation postflight. Specifically, the following elements in blood (pre- and postflight only) and urine will be evaluated: Adenocorticotrophic Hormone (ACTH), 17-Hydroxy-corticosterone (Cortisol), Angiotensin II, Renin, Aldosterone, Antidiuretic Hormone (ADH), Epinepherine, Norepinepherine, urine electrolytes (sodium and potassium), urine and plasma osmolality, extracellular fluid volume, total body water, Calcitonin, Serum Thyrocalcitronin, Parathyroid Hormone, Serum Throxine.

Background

Although many external influences contribute to the environment of the human organism as a whole, the environment of its basic unit, the living cell, is wholly internal. Since changes in extracellular fluid produce changes in the composition of the intracellular fluid, it is essential to the normal function of cells that the constancy of this fluid be maintained. This is achieved by the close interaction of several organ systems, the kidneys holding a predominant role. The kidneys are thus viewed as an organ which not only removes metabolic wastes, but actually performs highly important homeostatic functions by adjusting plasma volume and composition.

The necessity of elucidating the homeostatic control mechanisms which govern plasma volume and composition is evident when one realizes the complex and, as yet, unexplained interactions of these metabolic and endocrine controls. In man's constantly changing environment, there is a narrow margin of protective safety between normal, hypo and hyperfunction of these mechanisms. Evidence now exists to suggest that derangements of these normal mechanisms may play a significant role in man's adaption to gravitational stress.

Hardware

The hardware to support M073 and M071 are identical. Crew body mass will be determined by the Body Mass Measuring Device supplied by Experiment M172. Unconsumed food remanents will be mass measured by the Speciman Mass Measurement Device supplied by Experiment M074. Facilities for collecting urine, feces and vomitus are supplied by the Waste Management System of the Habitability/Crew Quarters, Experiment, M487. This experiment will also provide for urine sampling, specimen preservation (drying for feces and vomitus, and freezing for urine samples) and storage. In addition, M487 contains the food storage and preparation facilities including the water dispensing and measuring device.

Protocol

This experiment and the Mineral Balance Experiment, M071, are closely coupled and all of the data generated from M071 is required for M073. During the missions, combined urine samples will be collected for M071 and M073 and split postflight. In addition, operational data will be taken which will allow assessment of crew member metabolism. This consists of (1) a spacecraft humidity and temperature history, particulary excursions from the crew comfort range, (2) times of operation (mission elapsed time) and identification of participating crew member(s) in (a) Experiment M092, Lower Body Negative Pressure, (b) Experiment M171, Metabolic Activity, and (c) Extravehicular Activities, and (3) general crew activities (sleep periods, physical activities, etc.).

The experiment will be accomplished in three phases: (1) preflight, for 21 days, (2) inflight, and (3) postflight until re-adaptation has been established, beginning immediately postflight. The functions to be measured are identical to those for M071. Specifically:

A) Body weight (or mass) will be measured once daily immediately after the first urine voiding following the sleep period.

B) A standard diet of defined composition will be used since the composition of the crewman's diet must be known and carefully controlled. Preflight, each crewman will use this diet prior to the acquisition of baseline (or normal) data to allow the establishment of individual metabolic equilibrium. Every effort will be made to make the diet palatable.

C) Fluid can be taken as desired but all intake will be recorded. This includes fluid used for food reconstitution.

D) All urine will be collected pre- and postflight and preserved for analysis. Inflight, the amount of daily urine output from each crewman will be determined, and a measured, homogeneous sample of at least 120 mililiters taken, (45 ml for M071 and 75 ml for M073), frozen and stored for return as experiment data.

Data Return

During the Skylab Program, three men will occupy the orbital workshop on three different occasions. The initial mission will last for 28 days and the other two for 56 days each. The Bio-assay of Body Fluids Experiment will occur on all three missions so that by the end of the Skylab Program, a continuous quantitative assessment of the endocrinological adaptation for nine different individuals will have been obtained. For each individual, a preflight baseline will be obtained followed by a day-by-day profile of his physiological reaction to the space environment, and postflight, his re-adaptation to earth normal conditions. Specifically, the following data on a daily basis will be obtained preflight, inflight, and postflight:

1. All data obtained from Mineral Balance, Experiment M071.

2. Urine - concentration of the biochemical constituents specified in the Objectives.

In addition, blood samples will be taken periodically pre- and postflight and those parameters specified in the Objectives will be determined.

APPENDIX IV

Specimen Mass Measurement, Experiment M074

Principal Investigator: John W. Ord, Colonel, USAF, Medical Corps, Brooks AFB

Development Center: MSC

Integration Center: MSFC

Contractor: Southwest Research Institute, Inc.

Objectives

The objectives of this experiment are:

1. To provide the onboard capability for specimen mass measurement in support of the Mineral Balance Experiment, M071.

2. To demonstrate the feasibility of making mass determinations of 50 to 1000 gm objects in a gravity free environment using calibration masses.

3. To validate the theoretical behavior of the device under flight conditions which will include the finite mass of the spacecraft and the effects caused by spacecraft environment, including vibrations, tumbling, lift-off stresses, atmospheric and temperature variations.

Background

Studies from the Mercury, Gemini and Apollo Programs indicated that inflight bone and muscle deterioration occurs and this may adversely affect performance during extended space flights. Inflight experiments were designed to investigate these phenomena and the experimental protocol required determination of the masses of food residues, vomitus, and feces. To fulfill this need, a ground-based program was undertaken to provide a non-gravimetric mass measurement device which functioned independent of gravity. The concept chosen for the device depends upon timing the period of oscillation of a linear spring-mass pendulum system. The mass to be measured uniquely determines the period (seconds per cycle) of the device and by measuring this period, the mass of an object can be determined.

Hardware

The Specimen Mass Measurement Device is a self-contained unit capable of measuring the mass of objects ranging from 50 gms to 1000 gms in a zero gravity environment. The instrument consists of a specimen tray supported on springs attached to the bottom panel of an enclosing case. The tray is locked to prevent oscillation when not in use.

To operate the unit, the tray is unlocked and activated without an object on the tray to insure that the device operates smoothly with no rubbing or binding. The tray is secured and the object to be mass measured is placed on the tray and secured with the restraints provided. The pan is unlocked, latched in a position displaced 3/16 inches from the neutral point, and released. The latch is used to impart a known displacement to the spring system to initiate oscillation.

An optical unit sends a signal to the timer each time the measurement sensor crosses the midpoint in its oscillating cycle. The first two cycles are not counted in order that any noise produced by the release mechanism is dissipated. The next three cycles are counted. The device is shut down by activating the control lever which moves the measurement tray to the offset position, latches the trigger and sets the locking control to the lock position. The results are recorded and the measurement repeated. The total crew time required for the entire procedure is five minutes.

The Mass Measuring Unit requires power for the electronics subsystem. Two units are needed, one in the food preparation area and the other in the waste management compartment. Each unit weighs 33 lbs including the calibration masses. The dimensions are approximately 6 x 10 x 14 inches.

Protocol

Each instrument will be calibrated three times during the mission (early, middle and late in the mission) using the calibration weights of known mass. The stability of the instrument will be ascertained by a comparison of the three calibration curves obtained during the mission.

The Specimen Mass Measurement Device is vital to the success of the Mineral Balance Experiment, M071. All unconsumed food must be mass measured. All fecal material and vomitus passed by each crewman must be mass measured before being preserved by drying.

Data Return

The data return from this experiment will be the calibration curves generated at three different times during the mission, and the repeat mass measurement of the same object. The vast majority of the data will consist of that required to support M071. Specifically the mass of all unconsumed food and all feces and vomitus passed by each crewman taking part in the three Skylab missions will be measured.

The routine use of the Specimen Mass Measurement Device will validate the theoretical concept employed and will evaluate the design of this specific instrument.

APPENDIX V

Lower Body Negative Pressure, Experiment M092

Principal Investigator: Robert L. Johnson, M.D., MSC

Development Center: MSC

Integration Center: MSFC

Contractor: MSFC, Martin Marietta Corp.

Objectives

The experiment is designed to follow the time course of "orthostatic intolerance," or "cardiovascular deconditioning" in flight. This physiological process will be compared with the same phenomonon as it occurs in extended periods of bed rest.

Background

Cardiovascular deconditioning is a partial failure of the leg blood vessels to prevent excessive pooling of blood in the legs when the person assumes an erect posture in a gravity field. When this excessive blood pooling takes place, the rate of blood flow through the heart and lungs is less, causing the pulse pressure (difference between systolic and diastolic blood pressure) to be less, and the average pressure to be too low, causing reduced flow to the brain. Therefore dizziness and fainting are likely when the person stands up.

The Lower Body Negative Pressure (LBNP) experiment intentionally imposes a slight reduction of external pressure to the lower half of the body to test how the cardiovascular system reacts to a controlled amount of blood pooling during weightless flight. This will be done in Skylab to discover how quickly and how severely the condition progresses in the crew members during weightless flight.

Hardware

The inflight LBNP apparatus consists of three basic units: 1) a cylindrical tank with a waist seal into which the astronaut puts his legs and hips. It can be evacuated to a controllable pressure of 0-50 mm Hg below the ambient cabin pressure; 2) a leg volume measuring system which records the circumference of each leg at the level of the calf muscle;

3) an automatic blood pressure measuring system. It has an automatically inflatable arm cuff with a microphone for detecting blood flow and records systolic and diastolic blood pressure. The experiment also uses the vectorcardiogram equipment from M093 and the Body Temperature Measuring System from M171. The apparatus weighs 175 lbs and has a stowed volume of 59 cubic feet.

Protocol

The experiment is performed on each astronaut every three days, and an attending astronaut is needed to assist the subject for each performance of the experiment. The entire experiment takes about 60 minutes to perform. During the first half-hour the electrodes and sensors are attached to the subject and he enters the device and secures the waist seal. Then a 5-minute resting baseline recording is made of blood pressure, vectorcardiogram, leg volume, and body temperature. This is followed by 15 minutes of recording at successively lower pressure levels to a minimum level determined for each crewman. The experiment ends with a 5-minute post-negative pressure recording of the same parameters.

Data Return

The inflight vectorcardiogram, blood pressure, volume of both legs, body temperature, voice log, and the temperature and pressure of the interior of the LBNP device are either stored on tape or telemetered directly, depending on the availability of ground tracking coverage. At least once each day the data is to be returned to the ground tracking stations. The entries in the data log book are to be read down via voice link.

APPENDIX VI

Vectorcardiogram, Experiment M093

Principal Investigator: Newton W. Allenbach, M.D., USN Aerospace Medical Institute

Development Center: MSC

Integration Center: MSFC

Contractor: Martin Marietta Corp.

Objectives

This experiment is designed to measure the vectorcardiographic potentials of each astronaut periodically throughout the mission so that flight-induced changes in heart function can be detected and compared with changes caused by well-understood physiological stressors.

Background

The technique of vectorcardiography yields more information than the conventional electrocardiogram. In addition to detecting the electrical activity of the heart, which is common to both methods, the vectorcardiographic method of processing signals from the electrodes enables the investigator to directly infer the position of the heart inside the chest and its change in position at various instants during the heart beat cycle. This more precise information is necessary in analyzing heart function in weightlessness. The measurements will be done before and after the ergometer exercise of M171 and during the Lower Body Negative Pressure Experiment (M092) runs.

Hardware

The equipment consists of 1) a set of eight electrodes which are attached to the astronaut immediately before each experiment run; 2) a harness (or vest) which serves as a mechanical support for the connector between the individual electrode leads and cable. Pre-amplifiers are mounted on the harness and feed signals into the cable; 3) the VCG Electronics Module, which has a resistance network for converting the eight input signals from the electrodes into the three standard vectorcardiographic signals. This module is mounted on the

Experiment Support System (ESS) and contains circuits for computing and displaying the heart rate, and for measuring the electrode-skin resistance. The apparatus weighs 50 lbs and has a stowage volume of about 8.0 cubic feet.

Protocol

Every three days of the flight each astronaut is scheduled to perform VCG measurements before and after a two minute exercise period on the ergometer. An assistant is required to help the subject attach and remove the electrodes. Each experiment run takes about 45 minutes, including time to set up and attach the electrodes, run the experiment, take down the equipment, and stow it. The vectorcardiogram equipment is also used in the Lower Body Negative Pressure Experiment, (M092), and its use is described in that experiment protocol.

Data Return

The data is recorded on tape to be telemetered to the nearest ground tracking station. It consists of the three standard VCG analog voltage signals and a heart rate channel, along with voice identification of the conditions of recording. No equipment or samples are to be returned to the ground.

APPENDIX VII

Cytogenic Studies of the Blood, Experiment M111

Principal Investigator: Margery W. Shaw, M.D., NASA, MSC

Development Center: MSC

Integration Center: None

Contractor: None

Objectives

The objectives of this experiment are to make pre- and postflight determinations of chromosome aberration frequencies in the peripheral blood leukocytes of the Skylab flight crewmembers, and to provide in vivo radiation dosimetry.

Background

In mitosis, each chromosome duplicates itself with the duplicates being separated from each other at cell division. One duplicate chromosome goes into the nucleus of one daughter cell and the other duplicate goes into the nucleus of the second daughter cell. The end product of this process is cell division which involves several phases. Each phase is characterized by a particular pattern of chromosome behavior. It is during one of these phases (the metaphase), that chromosomal aberrations may be microscopically observed.

Chromosome analyses were done for all of the Gemini missions (with the exception of Gemini VIII which was terminated early) under the operational medical program. Significant, though slight, increases in some types of chromosomal aberrations were seen following some of the missions. This effect could not be correlated with mission duration, extravehicular activities, isotope injection of the crews or other obvious flight parameters. Observations on the Skylab crewmembers can assist in elucidating the mechanism of this phenomenon.

Measurement of the number of chromosome aberrations has been demonstrated by ground-based studies to be a sensitive method of biological radiation dose estimation. Ambient radiation encountered during long duration missions or unexpected solar flare events could produce significant increases in aberration levels. Even if no detectable increases in aberration levels are observed in the Skylab missions, the experiment will have served the useful purpose of demonstrating the lack of a detectable genetic hazard associated with these missions.

Protocol

Periodic blood samples will be taken pre- and postflight beginning one month before launch and terminating three weeks post recovery.

The leukocytes will be placed in a short term tissue culture. During the first cycle of mitotic activity in the *in vitro* cultures, standard chromosome preparations of the leukocytes will be prepared.

The leukocytes from the cell culture will be removed during metaphase and "fixed". A visual analysis will be performed which involves counting the chromosomes, the number of breaks, and types where possible, and then making a comparison between the identifiable chromosome forms with groups of chromosomes comprising the normal human complement.

Standard statistical procedures will be used to determine if a significant increase in chromosome aberration frequencies appears postflight. This analysis will include comparisons of preflight aberration levels in normal individuals of the general population. "Predicted" aberration levels for postflight samples will be calculated by using inflight physical dose radiation measurements and existing experimentally determined chromosome aberration production coefficients. The effects of any other operational or experimental procedure likely to produce chromosomal aberrations (such as radioisotope injections) will be measured on normal control subjects. These control subjects will comprise the Ground Control Group (GCG) and will be similar in age and physical attributes to the crewmembers. As control subjects the GCG will participate in all tests and medical procedures undertaken by the flight crewmembers. Examination will be made of the chromosomes of the ground control members and the flight crew prior to initiation of preflight procedures and tests to detect any chromosomal aberrations already present.

Hardware

No inflight hardware is required since the experiment is pre- and postflight. Ground base equipment consists of standard laboratory apparatus.

Data Return

The data from this experiment will consist of the chromosome aberration frequencies which appear postflight for nine men, three of whom will have experienced 28 days in earth orbit and the rest 56 days each. An estimate of the radiation dose experienced by each man will be made based on the number of chromosome breaks.

APPENDIX VIII

Man's Immunity, In Vitro Aspects, Experiment M112

Principal Investigators: Stephan E. Ritzmann, M.D., University of Texas, Medical Branch

William C. Levin, M.D., University of Texas, Medical Branch

Development Center: MSC

Integration Center: None

Contractor: None

Objectives

The objective of the experiment is to assay changes in humoral and cellular immunity as reflected by the concentrations of plasma and blood cell proteins, blastoid transformations and synthesis of ribonuleic (RNA) and desoxyribonucleic acids (DNA) by the lymphocytes.

Background

Information on man's humoral and cellular status of immunity and coagulation phenomena during and following exposure to space flight is essential before flight crews can be committed to extended missions. Significant alterations of the immunity mechanisms will produce prejudical effects upon this inherent defense system, thereby seriously compromising the crewman's operational status. The cellular immunity system is exquisitely sensitive to radiation, and the coagulation status is affected by man's activity.

The experimental program measures items which contribute to man's ability to combat infections and repair traumatized tissues after exposure to weightlessness, spacecraft atmosphere, sublethal ionizing radiation, the monotonous immunologic stimulation of a closed environment, and the unusual positioning and state of physical activity. Significant alterations of the humoral or cellular immune-mechanisms may produce detrimental effects upon normal physiological functions, may result in increased susceptibility to infections, and conceivably can induce the onset of autoimmune diseases.

Protocol

The experiment will obtain preflight baselines, which will be indications of normal metabolism, from the crewmembers and a Ground Control Group (GCG) composed of three men physically similar to the crew members who will serve as controls while the crewmembers are in spaceflight. Upon recovery after the spaceflight, information will be again obtained from the crewmembers before body functions "normalize" and compared with the preflight baselines and with the data being obtained from the GCG to detect any significant deviations. An extensive battery of analyses will be performed using appropriate laboratory techniques to detect qualitive and/or quantitative changes. Periodic examinations will be made of the blood proteins and lymphocytes until the possible altered concentrations are likely to have stabilized.

Hardware

No inflight hardware is required since the experiment is pre- and postflight. Ground based equipment consists of standard laboratory apparatus.

Data Return

The data from this experiment will consist of the results from the many analyses performed on the blood borne immunity systems. All nine members of the Skylab flight crew will participate.

APPENDIX IX

Blood Volume and Red Cell Life Span, Experiment M113

Principal Investigator: Philip C. Johnson, M.D., Baylor College of Medicine

Development Center: MSC

Integration Center: None

Contractor: None

Objectives

The objective of this experiment is to determine the effect of earth orbital missions on the plasma volume and the red blood cell populations with particular attention paid to changes in red cell mass, red cell destruction rate, red cell life span, and red cell production rate. The experiment is conducted pre- and postflight.

Background

The red blood cells (RBC) of the circulatory system provides the means of transporting oxygen from the lungs to all parts of the body. The oxygen carrying capacity of this system is proportional to the amount of RBC available. A decrease in RBC mass forces the system to compensate by increasing the heart rate, breathing rate, etc., at constant oxygen transport rates, and as a result, the ability of the cardiovascular system to meet peak oxygen demands is reduced.

Radioisotope studies on Gemini V and VII showed decreases in red blood cell mass while at the same time normal red blood cell survival times were shortened in three of the four crewmen. The production, distribution and destruction of red blood cells needs to be investigated in order to understand this RBC phenomena.

Protocol

This experiment has four parts; in each a different radioisotope tracer is used to evaluate the four red blood cell parameters outlined in the Objectives.

The site of red blood cell (RBC) production in the mature adult is the marrow of membranous bones (e.g. sternum and vertebrae) with the rate of production dependent on metabolic demands and the current red cell population. The rate of RBC production will be measured quantitatively by injection of a known quantity of a radioactive iron tracer into crewmembers. The radioiron, combined with globulin, is transported to other parts of the body. The iron (non-tagged and radioiron) which reaches the membranous bones is incorporated into the heme portion of hemoglobin by the bone marrow. Since not all the iron appearing in the plasma is used for erythrocyte production but is instead taken up by the iron pools of the body, a fraction of the injected radioiron will be unavailable for incorporation into developing RBC's. This can be determined by measuring the concentration of radioiron in the circulating RBC after seven days and comparing it with the initial concentration of radioiron in the plasma.

Since the rate of RBC production acts with RBC loss to increase or decrease the total RBC mass present at a given time, any changes in the rates of RBC production and destruction will be necessarily reflected in the red cell mass. Such changes in red cell mass will be measured and analyzed in the flight crewmembers by injection of radioactive chromium (in the form of sodium chromate tagged red cells. The sodium chromate diffuses through the cell membrane where it is converted to chromium chloride and, in this form, bound to hemoglobin. The volume of RBC's is then calculated by allowing the chromium-tagged cells to disperse through the circulatory system and measuring the extent to which the chromium has become diluted. The fact that chromium does not reenter the red cell makes it a good tracer for RBC mass determinations. Chromium incorporated into the hemoglobin structure of the circulating red cell also provides a means for estimating the rate of random cell destruction by monitoring the rate at which chromium disappears from the red cell mass.

To determine selective age dependent erythrocyte destruction and mean red cell life span, carbon 14 labelled glycine will be injected into a superficial arm vein of each crewmember and control subject. The glycine gives a cohort tag of the RBC's by its incorporation into the heme portion of hemoglobin and labels the erythrocytes during their development. Sequential blood sampling will then give the percentage of the label in the blood at a given time (days), and by plotting this data, a survival curve can be obtained. The resultant curve can then be analyzed mathematically and a mean life span of the cells determined. Only a small portion of the carbon 14 is re-utilized by the red cells making it an ideal RBC label.

Finally, plasma volume changes will be measured by adding a known amount of radioiodinated human serum albumin to each crewmember's blood. Albumin is a major constituent of the plasma and is the protein most responsible for maintaining the osmotic pressure at the capillary membrane. It acts to prevent plasma fluid from leaking out of the capillaries into interstitial space.

A ground control group, similar in age and physical attributes to the crewmembers will participate in all tests and medical procedures undertaken by the flight crew.

Hardware

No inflight hardware is required since the experiment is performed pre- and postflight. Ground-based equipment consists of standard laboratory apparatus.

Data Return

The data from this experiment will consist of the mass changes, production and destruction rates, and life span of the red blood cells from the Skylab crewmen, three of whom will have spent 28 days in orbit and the others 56 days each.

APPENDIX X

Red Blood Cell Metabolism, Experiment M114

Principal Investigator: Charles E. Mengel, M.D., University of Missouri, Medical Center

Development Center: MSC

Integration Center: None

Contractor: None

Objectives

The objective of this experiment is to determine if any metabolic and/or membrane changes occur in the human red blood cell as a result of exposure to the space-flight environment.

Background

In order to remain functional and effectively serve its purpose, it is necessary that the red corpuscle maintain an optimum osmotic balance against a steep ionic gradient, resist forces which try to change its biconcave shape to spherical and maintain an active transport mechanism which allows the passage of glucose and ions across the red blood cell membrane. Energy is required to accomplish these functions and most importantly, energy is required to maintain the corpuscle's ability to transport the oxygen required to maintain life in the body tissues. It is obvious that any interruption in the energy-giving metabolic process could render the red blood cell ineffectual and prove catastrophic to the astronaut.

This experiment will assess the influence of the spaceflight environment on the metabolic processes which support the crewmember's erythrocytes, and is designed to complement Blood Volume and Red Cell Life Span, Experiment M113.

Protocol

The red blood cell contains no glycogen. Consequently, for its continued metabolism, it must have constant access to glucose. The process by which the glucose penetrates the erythrocyte membrane is not known. However, it is an active transport process rather than simple diffusion. It is suspected that the membrane, in particular the lipid fraction, is functional in this process. Because the erythrocyte membrane is a dynamic component of the red corpuscle, its chemical composition and structural integrity will be addressed by this experiment. Standard laboratory techniques will be used.

The metabolic breakdown of glucose for energy production is accomplished anaerobically. It is through this glycolytic process that energy is stored in chemical bonds. To detect any changes in the glucose metabolic pathway that may occur as a result of spaceflight exposure, several key intracellular enzymes will be analyzed using standard laboratory techniques.

Hardware

No inflight hardware is required since the experiment will be performed pre- and postflight only. Ground based equipment will consist of standard laboratory apparatus.

Data Return

The data from this experiment will consist of the results from the analytical procedures, some 14 in all. All nine crewmen from the Skylab Program will participate.

APPENDIX XI

Human Vestibular Function, Experiment M131

Principal Investigator: Ashton Graybiel, M.D., Naval Aerospace Medical Institute, Pensacola, Florida

Development Center: MSC

Integration Center: MSFC

Contractor: Applied Physics Laboratory

Objectives

The purpose of the experiment is to examine the adaptation of the vestibular system to weightlessness. Specifically, the sensitivity and susceptibility of the astronauts to rotation and their preception of spatial orientation will be measured periodically throughout the flight.

Background

It is postulated that people will become susceptible to motion (or rotation) sickness and that this sensitivity to small rotations will change after spending a period of time in weightlessness. If people become more susceptible, then it will be difficult to design future space stations for artificial gravity by rotation of the spacecraft. Another predicted effect is that prolonged absence of gravity will change a person's sense of spatial localization.

Hardware

The equipment for this experiment consists of:

1. A litter chair which can be rotated by a motor at its base or, when not being rotated, can tilt forward, backward, or to either side.

2. A control console for selecting the mode of operation and speed and duration of rotation, and for displaying the speed and motor current.

3. An otolith test goggle with a bite-board mounting. The goggles contain an illuminated line which can be adjusted by the man to his perceived vertical or horizontal position.

4. A reference sphere with a magnetic rod, used by the astronaut to indicate body orientation non-visually.

5. A simple analog computer, called a "response matrix" which computes a running score of the subject's subjective responses during the motor susceptibility and rotation threshold tests.

The apparatus weighs 258 lbs., and has an approximate volume of 11.2 cubic feet.

Protocol

In the rotation threshold phase of the semi-circular canal test, called the "occulo-gyral illusion mode," the subject closes his eyes while the observer starts the chair rotating slowly in either direction. The subject pushes a button to stop the chair, and after it has stopped opens his eyes and reports any perceived motion of the target light of the goggles. This motion is the occulo-gyral illusion. If no motion is detected the chair rotation was below threshold. The rotational speed is increased in successive trials and his threshold is recorded.

In the motion susceptibility phase of the canal tests, called the "motion sickness sensitivity mode," the chair is rotated at a moderate speed for a minute and then the subject performs a pre-arranged series of head movements and reports his subjective sensations, which the observer records in the response matrix.

This sequence takes about 30 minutes and is to be performed with each crew member as a subject six times during the 28-day mission.

In the spatial localization tests, the subject is tilted to various positions relative to the spacecraft with his eyes closed and is asked to indicate both his perceived direction of gravity and body orientation. He indicates this both by setting the direction of an illuminated line in the test goggles and by lining up a magnetic indicator rod on a hand-held sphere.

The localization tests take about 45 minutes and are to be done on each astronaut three times during the 28-day mission. The tests are not to be done on the same day as the rotation experiments.

Data Return

The voice descriptions of the subject's symptoms, experiment conditions, and response matrix scores are recorded on tape and telemetered to the nearest ground tracking station. No samples are to be returned.

APPENDIX XII

Sleep Monitoring, Experiment M133

Principal Investigator: J. D. Frost, Jr., M.D.
Baylor Medical College

Development Center: MSC

Integration Center: MSFC

Contractor: Martin Marietta Corporation

Objectives

The purpose of this experiment is to objectively evaluate the quantity and quality of an astronaut's sleep patterns during prolonged space flight. This will be done by automated onboard monitoring, recording and analysis of EEG (Electro-encephalographic) and EOG (Electro-oculographic) data, with near-real-time telemetry of results.

Background

The M133 experiment embodies many significant advances over the methods used in the United States' first attempt to evaluate EEG patterns during Gemini 7. These include: (a) eliminating the need to pre-attach electrodes to the crewman's head by using caps with the electrodes in place; (b) capability for near-real-time monitoring and status assessment, rather than only postflight evaluation; (c) ability to remove signal artifacts caused by head or eye movements; and (d) automated inflight analysis of EEG activity, providing significant reduction of telemetry requirements and objective summary data.

Hardware

The major inflight hardware items required to support M133 are: (a) the cap assembly, which contains the signal sensors; (b) the preamplifier and accelerometer assembly, which fits on top of the cap; (c) the panel assembly, which analyzes, encodes, and records the EEG and EOG data; (d) analog signal tapes, for later more complete analysis and validation of telemetered data; and (e) crew logs, storage and return containers. Power and telemetry are supplied by the spacecraft systems.

Ground-based support facilities include telemetry recorders, analyzers, and displays of sleep-stage information.

Protocol

Crew participation in M133 is in three phases:

1. Preflight: Astronaut training, and baseline sleep data on three consecutive nights (10 hours total each night) recorded for one prime and one backup crewmember.

2. Inflight: Twenty-one specified nights of data on one crewman during regular 8-hour sleep periods.

3. Postflight: Three nights of sleep recording from same man as flight data (on nights +1, +3 and +5).

Five minutes are needed for preparation (for donning the sleep cap and hardware checkout) and five minutes after sleep (for doffing and stowage). No special crew activities are required to produce these EEG and EOG data, and normal sleep should not be interfered with by the cap and its associated equipment. This experiment will be performed on the first 56-day mission.

Data Return

The primary EEG and EOG data will be supplemented by crew self-reports on qualitative aspects of the astronaut's sleep status, such as comfort and dreams.

Inflight data analysis of EEG and EOG data will convert the analog signals to 3-bit binary codes for near-real-time telemetry, sampled once every 10 seconds. Seven discrete states will be encoded: awake, 4 stages of sleep depth, rapid eye movements (indicative of dreaming), and head movements. Uncoded continuous analog signals will be tape recorded and returned for more detailed postflight analysis and comparison with inflight telemetered data.

Real-time monitoring and display of sleep data will be available in the mission control center. It will show the astronaut's current sleep-state, cumulative time in each stage, and a graphic continuous sleep-profile display.

APPENDIX XIII

Time-and-Motion Study, Experiment M151

Principal Investigators: J. F. Kubis, Ph.D., Fordham University
E. J. McLaughlin, Ph.D., NASA/MM

Development Center: MSC

Integration Center: MSFC

Contractor: Martin - Marietta Corporation

Objectives

The objectives of this study are to evaluate the effects of space conditions on time-and-motion characteristics of crew performance, by measuring the similarities, differences, and relative consistencies between task activities in earth-based simulations and in zero-gravity spaceflight.

In support of these objectives, this experiment will photograph and analyze the following types of crew activities:

1) Locomotion and translation in the zero-g environment, with and without loads.

2) Fine and gross motor activities during operations with and without the use of restraints.

3) Long-term adaptations in the profiles of representative tasks.

Background

Visual records in the Mercury, Gemini, and Apollo programs have shown that the time-and-motion patterns of astronaut task performance may be affected by many factors, especially zero-gravity. Lack of recording equipment and operational constraints in those missions prevented the in-flight quantitative study of these effects.

Objective data on crew adaptions to zero-g would be valuable for the planning and design of crew tasks, restraints and tools, and evaluating the fidelity of present simulation techniques.

This experiment evaluates representative crew tasks that are performed as parts of other planned experiments and operations. The primary tasks that will be studied are:

a) Inflight Lower Body Negative Pressure (LBNP), Experiment M092: Biomedical preparation activities, including the Vectorcardiogram, Experiment M093, which involve on-the-body manipulative tasks requiring fine motor coordination and two-man interaction for successful completion; ingress to the LBNP device, which involves precision translation and fine motor coordination. Egress from the LBNP device is a backup study task.

b) Metabolic Activity, Experiment M171: Biomedical preparation activities, including use of the metabolic analyzer, translation to the bicycle ergometer, mounting and use of the ergometer. This ergometry task represents unique restraint problems and is one of the few lower torso work conditions in Skylab.

c) Specimen Mass Measurement, Experiment M074: Food preparation and specimen mass measurement at specific mission intervals. Food preparation is a vital long-term activity and mass measurement is a relatively simple repetitive operation.

d) Astronaut Maneuvering Unit, Experiment M509: These tasks involve (1) the disassembly and reassembly of relatively large equipment during replacement of the propellant supply cylinder to recharge the maneuvering unit, (2) translation during recharging operations, and (3) donning and doffing of the maneuvering unit.

e) Scientific Airlock Activity: Four experiments will be evaluated. Primary coverage will be derived from T027 (Contamination Measurement) and S149 (Micrometeorite Collection). Contingency coverage will be available from T025 (Coronagraph Contamination Measurement) and

S019 (Ultraviolet Stellar Astronomy). All of these involve tasks on large and bulky equipment that must be handled with delicacy and precision.

f) Operational Suit Donning and Doffing: These vitally important functions will be studied from the M509 and ATM activities.

Hardware

The inflight cameras, lights, voice recorders and task equipment are the same as the operational and experiment hardware needed for these other activities, and only additional film is directly required to support M151.

Inflight motion picture documentation for this study will consist of 38 400-ft. cassettes of 16 mm. color film. Their weight and volume are 28.0 lbs. in 0.304 cubic ft. for the 28-day mission (16 cassettes) and 19.25 lbs. in 0.209 cubic ft. on each of the two 56-day missions (12 cassettes).

Ground support facilities include recording of voice and TV communications. No additional monitoring equipment or training facilities are required for M151.

Protocol

Crew participation in M151 is in three phases:

1) Preflight: Astronaut training and baseline data are integrated with their training on the tasks and experiments to be covered by M151. These include neutral buoyancy tests, six-degree-of-freedom simulations, and KC135 zero-g trajectory flights.

2) Inflight: No special test-tasks are required. Observations are integrated with the performance of the other activities.

3) Postflight: Crew debriefing, and possible filming of activities that revealed problems, or for which preflight baseline data was not obtained.

Except for equipment setup (approximately 18 min.) and post-task securing (approximately 4 min.), no additional task time is required for M151 data. Task times will depend upon the tasks being studied. Schedules of observation are based upon the scheduling of those tasks.

This experiment will be performed on all three Skylab missions.

Data Return

Primary motion picture film data will be obtained at rates of two or six frames/second, depending on the tasks being studies. These visual records will be supplemented by crew voice comments and written logs.

Real-time monitoring will not be required. All M151 data will be statistically evaluated postflight. The results may be used to identify long-term performance adaptations and areas for special training or monitoring, validate ground-based time-line estimates and fidelity of simulations, and assist in planning and design of future work-aids and space facilities.

APPENDIX XIV

Metabolic Activity, Experiment M171

Principal Investigator: Edward L. Michel, NASA/MSC

Development Center: MSC

Integration Center: MSFC

Contractor: MSFC, Martin Marietta, Perkin Elmer

Objectives

The primary objective of this experiment is to determine if man's effectiveness in doing mechanical work is progressively altered by exposure to the space environment. Two secondary objectives are to evaluate the bicycle ergometer as an exercise device for long duration missions and to evaluate ground-based reduced-gravity simulators.

Background

Man's muscular system needs to be used to maintain its capacity and effectiveness to perform mechanical work; unused,it deteriorates. Since zero gravity relieves the mechanical stress on the musculoskelatal system, it is essential that a mission profile of the crew's work capacity and effectiveness be obtained. These parameters can be evaluated by metabolic measurements.

To date, metabolic measurement during U.S. flights has been limited to the determination of the total carbon dioxide production by the chemical analysis of the lithium hydroxide canisters. This method, although of value in determining average heat production rate for crewmen during space flight, does not provide insight into transitory (peak) energy expenditures associated with performance of work in space.

There has been a continuing ground-based program to ascertain the metabolic cost of working under conditions that simulate the environment of space. The results of these ground-based studies will be compared with the metabolic measurements made during an actual space mission.

Hardware

The equipment consists of a metabolic analyzer, a bicycle ergometer and a body temperature measuring system. In addition, Experiment M093 - Vectorcardiogram, and the blood pressure measuring system provided for Experiment M092 - In-flight Lower Body Negative Pressure, is required.

The metabolic analyzer is an electromechanical device which measures oxygen consumption, carbon dioxide production and minute volume (the average volume of air inspired per minute). The major components of the analyzer are an inspiration spirometer (a device for measuring the volume of air entering the lungs), and expiration spirometer, a Mass Spectrometer for measuring oxygen, nitrogen, carbon dioxide and water vapor concentrations, and a calibration assembly. The analyzer electronics are also capable of computing vital capacity and the respiration quotient (ratio of carbon dioxide expired to oxygen consumed).

The ergometer is a rotary bicycle-type device designed to allow a subject to exercise in zero gravity using eigher his hands or his feet. It is capable of automatically programming heart rate by a feedback control which varies the load to produce the desired heart rate over a range of 100 to 200 beats per minute. Heart rate is derived from the vectorcardiogram system. It is also capable of manually selecting a constant work load. Body temperature is measured by an individually fitted ear probe and associated electronics.

All of the data derived from this experiment is recorded on the spacecraft tape recorder and transmitted to the ground at a later time. Manual data recording is available as a backup mode. Voice comments are also recorded. Motion picture data will be obtained using the operational data acquisition camera with film provided by Experiment M151, Time and Motion Studies. The weight of the hardware for the metabolic activity experiment is 575 lbs.

Protocol

The metabolic activity experiment will be conducted on each crewman five times in the 28-day mission and eight times during the two 56-day missions, with test sessions spread evenly throughout the mission.

The test procedure consists of measuring the selected physiological parameters of a subject who follows a prescribed pattern of activity on the ergometer. First, the resting state values of body temperature, heart and metabolic rates are measured setting the baseline for these parameters, then duplicate measurements are made of vital capacity and respiratory reserve. A period of programmed exercise on the ergometer is performed followed by a resting period. Blood pressure measurements are taken automatically during the test procedure.

The test procedure is performed five times in the 12 months preceding launch. Three days prior to launch an exercise tolerance test will be performed.

At 12 and 24 hours after postflight recovery, each crewman will be given an exercise tolerance test. In addition, if there are any significant changes in metabolic performance during the course of the mission, the physiological parameters will be followed using the inflight procedures. This will be repeated every three days until baseline levels are reached.

Data Return

The data return from this experiment will consist of the profiles which occur during a prescribed exercise regime in zero gravity for the following variables: body temperature, blood pressure, heart rate, vectorcardiogram and metabolic rate. The metabolic rate is computed from measurements of oxygen consumption and carbon dioxide production.

These profiles of the physiological parameters will be obtained five times for each of three men on the 28-day mission and eight times per man for the two 56-day missions. Together with the pre-flight data, the effect of the spaceflight environment on man's ability to perform mechanical work will be evaluated. Decrements in performance will be indicated by elevations in heart rate at a fixed work load or a decrease in work output at a fixed heart rate. The ergometer has the capability of operating in either mode. The effectiveness of the crewman to perform mechanical work is measured directly by the metabolic rate.

APPENDIX XV

Body Mass Measurement, Experiment M172

Principal Investigator: John W. Ord, Colonel, USAF Medical Corps, Brooks AFB

Development Center: MSC

Integration Center: MSFC

Contractor: Southwest Research Institute, Inc.

Objectives

The objectives of this experiment are to demonstrate the feasibility of body mass measurement in the absence of gravity, to validate the theoretical behavior of the Body Mass Measuring Device, and to support those biomedical experiments requiring body mass determination.

Background

Studies from the Mercury, Gemini and Apollo Programs indicated the requirement for extensive inflight biomedical investigations. An integrated battery of experiments were designed for the Skylab missions and there arose from these experiments, a need for inflight measurements of the crewman's weight or mass. Since the normal ground based weighing techniques require gravity for their operation, a program was undertaken to provide a mass measurement device which functioned independent of gravity. The concept chosen for the device depends upon timing the oscillating period of a linear spring-mass pendulum system. The mass to be measured uniquely determines the period (seconds/cycle) of the device and, by measuring this period the body mass of a crewman can be determined.

Hardware

The Body Mass Measurement Device is a linear spring/pendulum chair system. When moved, the inertia of the mass in the chair causes a pendulum cycle, the period of which is determined by the mass being measured. The device electronically times the period of the pendulum and directly displays the results for determination of body mass.

To operate the device, the subject positions himself in the chair and fastens the restraint system. The electronics are turned on and the readout display cleared by activating a reset switch. A control lever releases a lock and the chair begins to oscillate. The control lever is used to impart a constant displacement to the spring system to initiate oscillation.

An optical unit sends a signal to the timer each time the chair crosses the midpoint in its oscillating cycle. The first two cycles are not counted in order that any noise produced by the release mechanism is dissipated. The next three cycles are counted and timed. The device is shut down by activating the control level which moves the measurement seat to the offset position, latches the trigger and sets the locking control to the lock position. The results are recorded and the measurement repeated twice. The total crew time required for the entire procedure is 5 minutes.

The device is self-contained, requiring only power for the electronics subsystem. In the stowed position, it measures 20 inches high, 24 inches long, and 30 inches wide. In the operating position it measures 31-1/4 inches by 35-1/4 inches by 30 inches wide. Flight weight is 75 lbs. The device will be calibrated using existing flight hardware of known mass.

Protocol

The mass of each crewman will be measured once each 24 hours immediately after the first urination following the sleep period. This information is in direct support of Mineral Balance, Experiment M071, Assay of Body Fluids, Experiment M073, and Metabolic Activity, Experiment M171.

The device will be calibrated three times during each mission (early, middle and late in the mission).

Data Return

The data return from this experiment will be the daily mass measurement of each crewman taking part in the three Skylab missions. The day-to-day fluctuations and the mission profile will be determined for nine different men.

The routine employment of the Body Mass Measurement Device will evaluate the design of this specific instrument.

APPENDIX XVI

Effects of Zero-G on Single Human Cells, Experiment S015

Principal Investigator: P. Montgomery, M. D.,
Dallas County Hospital

Development Center: MSC

Integration Center: MSC

Contractor:

Objectives

The experiment is designed to measure the cellular functions of living human cells in a tissue culture while they are subjected to weightless space flight. Several biochemical measurements will be made, and the cells will be photographed in flight.

Background

In order to determine what effect gravity has on individual cells, a complete survey of cellular structure and biochemical function is necessary. The investigator has previously measured a wide variety of chemical and structural changes in high gravity fields and in one g, but there is as yet no knowledge of sub-gravity effects. The cells will be examined with time lapse microscope photography at magnifications of 40X and 20X. Two separate groups of cell cultures will be maintained in space for four and 10 days, respectively. After several biochemical experiments are performed semi-automatically, the cells will be preserved in space and returned for further chemical tests in the laboratory. The experiment will measure DNA, RNA and lipid content of the cells and enzyme activity. The DNA turnover will be measured by labeling with radioactive tritiated thymidine. Postflight examination of the cells in the electron microscope will be performed.

These zero-g studies will be combined with the same measurements at one and 200-300 times earth gravity in order to synthesize a gravity profile of the complete response of human cells to gravity fields.

Hardware

The apparatus consists of 1) a microscope camera system with two separate culture chambers, pre-focused microscope optics and 16 mm film reels for 40X and 20X magnification time lapse photographs; 2) two separate assemblies of 12 culture chambers each, along with pumps and fluid reservoirs for feeding the cultures, removing their waste products, adding radioactive solutions and rinse water, and preserving the cells; 3) a clock mechanism for timing the signal lights which indicate the state of the system to the astronauts.

Protocol

The experiment will be set up and the optics pre-focused before launch. The crew is to check the operation of the lights on the unit twice a day for the first 10 days of the mission. On the fourth and tenth day of flight a crew member must activate a cycle which injects radioactive labels and fixatives used in each of the 12 cultures. On each day the experiment is run, one astronaut's intermittent attention is needed for two hours and twenty minutes. The experiment package is active throughout the flight, but is not monitored after the tenth day. The experiment housing must be returned to the principal investigator intact.

Data Return

All of the data is in the returned experiment package, some as undeveloped film and the rest as the preserved cells. Extensive histochemical analysis will be done in ground-base laboratories and the results will comprise the bulk of the data return from this experiment.

APPENDIX XVII

Circadian Rhythm Pocket Mice, Experiment S071

Principal Investigator: Dr. Robert G. Lindberg, Northrop Corporation

Development Center: ARC

Integragation Center: MSC

Contractor: Northrop Corporation

Objective

The purpose of the experiment is to find out whether the daily physiological rhythms of a mammal are altered in space flight.

Background

If the stability (precision) or the period of physiological rhythms change significantly during flight, then there is a strong indication that bio-rhythms of animals on earth are timed by some factor (or environmental force) which is absent or significantly altered in space. This, along with similar evidence from the Vinegar Gnat Circadian Rhythm Experiment (S072), would imply that weightless space flight alters the functioning of basic control mechanisms for metabolic activity. The maintenance of normal biological rhythms in man during space flight is important to his well-being and effectiveness in space.

On the other hand if the pocket mice in space continue their terrestrial bio-rhythms, then we can conclude that space conditions impose no stress on the basic biological clock mechanism and that man's performance will not be degraded because of rhythm disturbances.

Hardware

The equipment for this experiment consists of cages and a life support system for six pocket mice, and a data system which is shared with S072 (the Vinegar Gnat Experiment).

The animals are kept in constant darkness and isolated from sound and smell sensations. An environmental control system maintains an atmosphere equivalent to sea level pressure and composition, a temperature of 60°F and a relative humidity of 60%. The apparatus is mounted with S072 hardware and packaged as a unit weighing 235 pounds and occupying a 43"x25"x20" volume.

Protocol

Six pocket mice will be enclosed in a dark, constant temperature, atmospheric pressure chamber for approximately three weeks immediately before flight. Continuous measurements will be made of their body temperature, heart rate, and activity level in order to establish the natural period, phase, and stability of the rhythms. The experiment chamber will then be launched in the Service Module and the same measurements continued throughout flight.

The equipment is completely automatic in flight. The only astronaut task is to operate back-up controls at the request of the ground crew in the events of malfunction or emergency.

Data Return

The body temperature, heart rate and activity level of the six pocket mice will be telemetered to a ground station and relayed to the principal investigator for interpretation.

APPENDIX XVIII

Circadian Rhythm - Vinegar Gnat, Experiment S072

Principal Investigator: Colin S. Pittendrigh, Stanford University

Development Center: ARC

Integration Center: MSC

Contractor: Northrop Corporation

Objectives

This experiment is designed to find out whether the daily emerging cycle of vinegar gnat (drosophila) pupae is altered in space flight.

Background

Extensive experiments have shown that even though gnats in the pupae stage develop at different rates depending on temperature, they will not emerge from the pupae as adult gnats until some kind of internal signal is given off. This triggering signal is somehow timed to occur at an exactly fixed time delay after a flash of light, and it occurs at the same daily time interval thereafter, regardless of the temperature. The experiment will measure the emergence times of pupae in two groups, one at 15°C and the other at 20°C, to find out whether space flight conditions change the mechanism which keeps the rhythm constant despite changes in temperature. Each of the two temperature groups is further divided in half so that they can be initiated by the synchronizing flash at two different times, 12 hours apart. If the delayed group shows the same rhythms of emergence response as the earlier group, then it is likely that no external factor contributes to the rhythm behavior and that the rhythms are internally synchronized.

This experiment and Circadian Rhythm of Pocket Mice, Experiment S071, tests the stability of bio-rhythms in two completely different kinds of living systems - insects and mammals, respectively. If both rhythm systems become disrupted during the Skylab mission then we can say that space flight affects some kind of basic process common to both rhythm mechanisms, and it is likely that man's biological clock mechanism will be similarly affected.

Hardware

The apparatus consists of four identical chambers, each containing about 180 pupae placed immediately above 180 photocells. The temperature of all chambers is held at 5°C until the experiment is initiated in orbit, at which time two are raised automatically to 15°C and the other two chambers are brought to 20°C. After the specimens are synchronized with white light, a dimmer red light is turned on every 10 minutes and the 180 photocells are scanned electronically. If a gnat has emerged, the corresponding pupae will be transparent and its photocell will be activated. The information about the emerged pupae is stored in the memory of the data system. One of the chambers at each temperature will be synchronized (with the white light) 12 hours later than the other one, as described above. The apparatus is mounted with the S071, hardware and packaged as a unit weighing 235 lbs. and occupying a 43" x 25" x 20" volume.

Protocol

The equipment is installed in the Service Module shortly before launch and is completely automatic in flight. The only astronaut task is to operate backup controls at the request of the ground crew in the event of a malfunction or emergency.

Data Return

The data will be telemetered to a ground station for interpretation. It will consist of the rate of pupae emergence events versus time. This rate should reach a maximum once a day with a definite time delay after the initial synchronizing flash.

CHAPTER THREE

SOLAR PHYSICS

EXPERIMENT PROGRAM BACKGROUND

Rationale

The sun certainly is one of the most widely studied objects in the sky; yet it remains poorly understood. Such questions as the origin of solar flares, the development and decay of active regions (sunspots, plages and prominences) and the temperature characteristics of the corona (the diffuse region extending millions of miles above the solar surface) remain with us today. Until recently it was possible to observe solar emissions only at wavelengths which could penetrate the earth's atmosphere. This meant visible and radio emission. Thus the vital ultraviolet and x-ray regions of the solar spectrum are cut off from earth-bound viewing. In addition, the daytime atmospheric scattering of visible light causes the sky to be much brighter than the solar corona. Thus rare solar eclipses are the only opportunity to view the extended solar corona.

There are three major aspects of solar research:

a. The sun has a very important influence on the earth. It is the ultimate source of all energy on the earth, and all terrestrial life depends upon the sun. It controls our environment and is responsible for our ionosphere, which is crucial for radio communication and shielding of terrestrial life.

b. The sun is the nearest star. The sun is thus the "Rosetta Stone" of stellar astronomy. Understanding of the stars depends on our understanding the sun.

c. The sun is an astrophysical laboratory close at hand. The proper combination of volumes, pressures, and temperatures required for stellar phenomena cannot be created in earth-based laboratories, but by using the sun we can study atomic, nuclear and plasma physics, aerodynamics, hydrodynamics, and magneto-hydrodynamics.

Through the use of the ATM to study the sun, we look forward to a better understanding of the following solar physics problems:

a. How is the corona heated?

b. What is the nature of the atmospheric structural detail, such as spicules?

c. What do coronal streamers look like in space?

d. What is the relationship between these streamers and surface features?

e. What are solar flares?

f. How do active regions evolve?

History

Making use of sounding rockets, balloons and small unmanned spacecraft we have been studying the sun from space and near-space since the end of World War II. From these studies we have learned much about the general nature of the sun in the x-ray and ultraviolet regions. The first rocket ultraviolet spectrum of the sun was obtained in 1946. The first x-ray image of the sun was obtained from a sounding rocket in 1960. Using orbital spacecraft, such as Orbiting Solar Observatories (OSO), Orbiting Geophysical Observatories (OGO), and the U. S. Navy SOLRAD satellites we have gained a great deal of insight into solar processes. However, our ability to obtain observations of sufficiently high resolution in energy, time, and space is limited by the size of the instruments which can be carried by these spacecraft.

Phenomena occur on the sun over areas smaller than we can presently resolve, and in time intervals shorter than we can resolve without larger, more sensitive instruments. Spectroscopy, the resolution of light into different energies, is our most valuable tool for study of celestial bodies. With larger instruments we can improve our capability to obtain finer energy resolution.

ROLE OF SKYLAB

There are several basic features of the sun's emission which are of interest to solar physicists. The first of these is called the hydrogen alpha emission. This is a red light emitted by the hydrogen gas present near the solar surface. The total visible emission of the sun changes only very slightly during solar flares; however, the hydrogen alpha emission is greatly enhanced and has been a fundamental feature of flare and active region studies for some time. The hydrogen alpha images will be available to the astronauts to assist them in finding interesting portions of the solar disk to study with the ATM instruments. There are two hydrogen alpha cameras on board the Skylab ATM.

Several of the ATM instruments will study a region of the solar atmosphere called the chromosphere. This region is 500 to approximately 2,000 miles above the surface of the sun and is where the hydrogen alpha emission occurs. The temperature in this region is rapidly increasing from 5,000°C to more than 100,000°C. The much higher temperatures of the chromosphere give rise to the ultraviolet radiation. The ultraviolet radiation will be studied in terms of particular emission features at specified wavelengths. These studies will help us understand the types of atoms present in this region under various phases of solar activity and possibly shed some light on the mechanism which supplies the heat to this region. There are three different ultraviolet detector experiments on ATM and an additional ultraviolet detector operated form the Skylab scientific airlock.

The solar corona begins about 2,000 miles above the solar surface and continues far into space. The density of matter in the corona is quite low, but the temperatures vary from almost a million degrees in quiet regions to tens of millions of degrees in certain regions during solar flares. These high temperatures cause the ions and electrons in the corona to radiate x-rays. There will be x-ray telescopes on ATM equipped with cameras to photograph the x-ray corona of the sun.

Because the corona is so large and hot, many free electrons are available to scatter the white visible light radiated from the surface of the sun. This scattered light is very much weaker than the radiation from the solar surface. A coronagraph is an instrument capable of studying the faint corona without viewing the bright solar surface. Since the intensity of scattered light is a measure of the electron density in the corona, photographs taken out to 3 million miles from the solar surface will give us the first look over an extended period of time at the corona.

Skylab, and in particular the Apollo Telescope Mount (ATM), will carry more than 2,200 lbs. of solar instrumentation. The total weight of the telescope mount is 22,300 lbs. The ATM is mounted on a truss support structure which surrounds the airlock module and multiple docking adapter. The ATM canister is approximately 11 feet long and 9 feet in diameter. The five ATM experiments will be mounted inside the canister, carefully aligned so that each experiment points toward the same spot on the solar surface. No astronomical instrument on earth or in space is perfectly rigid. Yet the ATM system can remain stable to within 1/700 of a degree for a 15-minute period. This minimizes the blurring of solar images and will allow detailed resolution of features approximately 1,000 miles in size on the solar surface when short exposures are taken.

FUTURE DIRECTIONS

Already, solar astronomers are mapping the future strategy for research on the sun. We know that higher resolution of surface detail on the sun is necessary to the understanding of many solar processes. But to a very large degree, the research emphasis and the phenomena to study, will be influenced by the Skylab results. Hence the future direction of solar research depends upon the analysis of the ATM observations.

APPENDIX I

The H-Alpha Telescopes

Principal Investigator: None

Development Center: MSFC

Integration Center: MSFC

Contractor: Perkin-Elmer

Objectives

Two telescopes sensitive to the red hydrogen alpha light of the sun will take TV and photographic pictures of the solar disk. The H-alpha telescopes will provide the primary means for the boresight pointing for the ATM experiment package. Correlations with UV and X-ray phenomena will be made with the H-alpha photographs taken by these cameras.

Background

Hydrogen is by far the most abundant element on the solar surface. One of the strongest emission features characteristic of hydrogen is the H-alpha red light. Since this light is in the visible portion of the spectrum, it has been studied for years from earth-based telescopes. When flares occur, generally the total white light energy output of the sun is changed insignificantly. However the H-alpha emission is enhanced tremendously and the amount of H-alpha emission resulting from a flare is the primary mode of classifying the size of the flare region.

Hardware

There will be two H-alpha telescopes on Skylab. One will be equipped with a beam splitter for simultaneous photographic and television pictures. The other telescope will be operated in the TV mode only. Both telescopes will be equipped with a Fabry-Perot filter to make precise observations at the desired wavelength. A zoom capability will allow specific portions of the solar disk to be viewed in detail.

One telescope weighs 190 lbs. and is 9' long and approximately 1' in diameter. The second telescope which is not used for photographic purposes is 5' long, 1' in diameter and weighs 110 lbs.

Protocol

The H-alpha telescope will be one of the "eyes" of the astronaut. Active regions will be followed as they traverse the solar disk. When flares are observed, the amount of H-alpha emission will be correlated with emission intensities in other energy regions.

Data Return

The film taken with the large H-alpha telescope will be retrieved during the normal extravehicular activity events scheduled. The film will be removed and replaced from the center work station of the ATM canister.

APPENDIX II

XUV Spectrograph/Spectroheliograph, Experiment S082

Principal Investigator: R. Tousey, Naval Research Laboratory

Development Center: MSFC

Integration Center: MSFC

Contractor: Naval Research Laboratory, (Sub-contractor: Ball Brothers Research Corporation)

Objectives

These experiments will photograph the sun in selected ultraviolet wavelengths. Resulting photographs (spectroheliographs) will show specific emission features greatly enhanced over that observed of the solar disk in white light. The sun will therefore appear quite "blochy" with much of the emission confined to active regions. The spectroheliograph will cover the wavelength region from 150 to 650 Å (called the far ultraviolet region). A second instrument will take data highly resolved into wavelength in the middle and near ultraviolet region. This instrument can be pointed anywhere on the solar disk and obtain the detailed emission characteristics of a region only 1,000 miles wide.

Background

The solar chromosphere and lower corona are much hotter than the surface of the sun characterized by the H-alpha and other visible emission. To observe these hotter regions of the solar atmosphere one must observe in the ultraviolet or even the x-ray region. Rockets and OSO satellites have taken ultraviolet spectra and photographs of the sun. Rocket payloads allow the return of photographs but exposure time is short and catching a flare in progress with rockets is a difficult task. The unmanned OSO satellites do not allow the return of high resolution film. Thus Skylab will allow long periods of continuous monitoring of the sun required for proper ultraviolet studies and man will be able to return the film and direct the spectrograph to interesting features.

Hardware

The spectroheliograph/spectrograph are two separate instruments with separate housings. The spectroheliograph ("A" instrument) consists of a concave grating which separates the UV light into its various wavelength components from 150 to 650 Å. Images of the solar disk are formed on film at specific positions corresponding to wavelength. The "A" instrument weighs 252 lbs., is 10' long and 3' x 1-1/2' in cross section.

The spectrograph ("B" instrument) consists of a mirror and entrance slit which will select portions of the solar disk or limb (edge) to be viewed. A set of two gratings will spread the ultraviolet region from 970 Å to 3940 Å onto photographic film. The "B" instrument also contains an X-UV monitor which allows the sun to be viewed by the astronauts on TV in the X-UV regions. The "B" instrument weighs 373 lbs. and is essentially the same size as the "A" instrument.

Protocol

The astronaut will take photographs of the sun with the spectroheliograph. The astronauts will select the wavelength range to be studied and the exposure time.

The "B" instrument will be used to take spectra at various portions of the limb or solar disk. The astronauts will select the mode of operation and the wavelength region to be covered.

The X-UV monitor provides a display of the 150-650 Å activity and gives an indication of X-UV images being taken photographically by the "A" instrument.

Data Return

Film containing the disk images of the "A" instrument and the spectra of the "B" instrument will be retrived and replaced by the astronaut during the planned extravehicular activities. The NRL instruments require the film to be retrieved from the front of the ATM canister. The TV pictures are transmitted to the ground and recorded.

APPENDIX III

UV Scanning Polychromator Spectroheliometer, Experiment S055

Principal Investigator: L. Goldberg, Harvard College Observatory

Development Center: MSFC

Integration Center: MSFC

Contractor: Harvard College Observatory, (Sub-contractor: Ball Brothers Research Corporation)

Objectives

To observe temporal changes in the EUV (Far Ultraviolet) radiation emitted by several types of solar regions. The instrument is capable of accurately measuring the strength of certain emission features of elements with high time resolution in various stages of ionization. It observes 7 emission lines in the wavelength region from 300 to 1350 Å. Simultaneous observations of chromospheric and coronal layers of flares will be obtained. The energy radiated in selected emission lines in the EUV region will be measured. The instrument operates photoelectrically and requires no film.

Background

The EUV region of the solar spectrum is generated in the chromosphere and lower corona. Time development of phenomena relating to solar active regions and flares is important. Because of the rapid response of electronic scanning techniques, the time dependence of EUV emission features will be obtained in regions of interest on the solar disk and limb.

Hardware

The EUV radiation from the sun enters this instrument and is reflected by a mirror which is movable along both axes. The mirror is adjusted to place the desired square segment of the solar surface on to a spectrometer grating. The remainder of the light is reflected back out of the instrument. The EUV radiation is broken up into its spectral components and received by 7 detectors. The 8th detector is in the zero order position and hence sees light at all wavelengths. The zero order detector indicates whether or not the solar disk is being viewed.

No film is used. All data is recorded electronically. The instrument is 10' long, 2' x 2' in cross section and weighs 345 lbs.

Protocol

The astronauts will initiate raster scans which will cover entire regions of the disk. They will also align the H-alpha telescope image, which will be set on the limb of the sun, with the pointing direction of the S055 instrument by observing the loss of light in the zero order detector as the entrance slit passes the limb of the sun. The two instruments will then be in alignment.

Data Return

Because no film is used, this instrument has no extravehicular activity requirement. Also, this instrument may be operated in an unmanned mode between the manned visits of Skylab.

APPENDIX IV

X-ray Spectrographic Telescope, Experiment S054

Principal Investigator: R. Giacconi, American Science and Engineering

Development Center: MSFC

Integration Center: MSFC

Contractor: American Science and Engineering

Objectives

S054 will take X-ray photographs in 6 wavelength bands from 2-60 Å. The resulting photographs will be x-ray images of the solar disk. Time development of x-ray producing events (flares and active regions) will be obtained in the various x-ray wavelengths. A transmission grating will be placed behind the telescope mirrors to obtain x-ray spectra of active regions of the sun.

A small 3" grazing incidence instrument placed in the unused central portion of the larger telescope is used to provide a "live" picture of the sun in x-rays for the astronaut to view. This aid will complement the H-alpha images on TV and will assist the astronauts in obtaining the best possible data from the ATM.

Background

It has been known for many years that the sun emits x-rays; however, the detailed nature of this emission is only now becoming available. OSO spacecraft are returning spectra of the sun's x-ray emission; yet, the spatial distribution of x-ray emission is only crudely known. Since x-ray intensities associated with solar flares are greatly enhanced over that observed for the "quiet" sun, photographs of flare events are very important. Corona temperatures and energetic particle densities will be obtained from these photographs which may then be correlated with EUV and H-alpha photographs.

Hardware

The x-ray telescope consists of two concentric mirrors of highly polished metal alloys to intercept the x-radiation and focus it at grazing incidence. Filters of beryllium, aluminized mylar and other materials with varying thickness will select the x-ray wavelength band to be photographed. A transmission grating will also be used in conjunction with the filters to obtain information on the spectral features of the x-ray emission. A small grazing incidence telescope placed in the unused central portion of the larger telescope provides x-ray images for the astronaut's use in monitoring the solar x-ray activity. Photomultiplier tubes will also give a measure of overall solar x-ray activity.

The S054 telescope is more than 300 lbs. in weight and is 10' long and 1-1/2' in diameter.

Protocol

The astronauts will obtain photographs of the solar disk. Special rapid photographic sequences may be initiated during flares and x-ray events. This experiment will be operated in an automatic mode when Skylab is unmanned.

Data Return

Film is the primary form of data return for this experiment. It will contain the x-ray images and spectra. The film will be resupplied and retrieved from the rear of the ATM canister during the scheduled extravehicular activities of the astronauts.

APPENDIX V

Dual X-ray Telescopes, Experiment S056

Principal Investigator: J. Milligan, Marshall Space Flight Center

Development Center: MSFC

Integration Center: MSFC

Contractor: Marshall Space Flight Center

Objectives

This is an x-ray experiment which has two goals. The first is to take x-ray photographs in six bands from 3-60 Å and the second is to observe the total x-ray emission of the sun in the wavelength region from 2.5-20 Å in ten channels. X-ray photographs are taken with a smaller version of the S054 x-ray grazing-incidence telescope. The second is to obtain good time resolution of solar x-ray emission which will be available from the proportional counter systems. This is recorded and displayed in instantaneously for the astronauts. An x-ray history has proven to be an excellent indicator of solar activity. The proportional counters and the x-ray telescope are separate systems.

Background

Since this instrument covers much of the same x-ray region as S054, many comments concerning that experiment will also apply to this one. The proportional counters on the x-ray event analyzer will give spectral information with very good time resolution. The intensity and time information will complement the data taken by other experiments in establishing the detailed nature of flare emissions and other x-ray events.

Hardware

The x-ray telescope portion of the instrument is a double reflecting grazing incidence mirror which focuses the x-radiation on to photographic film. The x-ray region from 3-60 Å is covered with spectral resolution determined by filters placed in front of the telescope. Two proportional counters cover the 2.5-20 Å region in 10 channels giving spectral and temporal information on x-ray events. The x-ray activity level is displayed in analog form on the control panel. The total package is 9' long and 1-1/2' in diameter and weighs 354 lbs.

Protocol

The level of operation of this experiment is determined by solar activity. The astronauts will either select the patrol or single frame mode during quiet times or various active modes which will take more photographs per unit time. The astronauts will also acquire targets of interest to be photographed.

Data Return

Data is returned from the x-ray telescope on film retrieved and replaced during scheduled extravehicular activities from the center work station of the ATM canister. The data from the proportional counters is recorded in analog form. There will be no provision for this experiment to operate during the unmanned phases of this mission.

APPENDIX VI

White Light Coronagraph; Experiment S052

Principal Investigator: Dr. R. MacQueen, High Altitude Observatory

Development Center: MSFC

Integration Center: MSFC

Contractor: High Altitude Observatory, (Sub-contractor: Ball Brothers Research Corporation)

Objectives

The solar coronagraph views the corona out to 3 million miles (6 solar radii) in visible light. Measurements of polarization, shape and intensity will be available by photographs taken at rates up to one every 13 seconds. Thus rapidly moving material may be photographed as it leaves the sun. Since the sun rotates correlations will be made with surface features as they move into proper position on the limb of the sun. The systematic changes in the extent of the corona will be apparent over several solar rotations of 28 days.

Background

The solar corona is a region of very high temperatures (more than a million degrees) and very low pressures. Because most atoms are highly ionized under these conditions, great numbers of free electrons are present. These electrons are capable of reflecting the light from the solar surface. During eclipses the solar corona is seen to extend outward by great distances. Earth based coronagraphs are hampered because local sky brightness is greater than much of the corona. Present coronagraph measurements indicate that matter is often transported at relativistic speeds outward in association with events on the surface of the sun at the limb.

Hardware

The coronagraph uses an externally mounted disk system which occults the brilliant solar surface while allowing the fainter radiation of the corona to enter an annulus and be photographed. Polaroid filters will be used to determine the polarization. A mirror system will allow either TV viewing of the corona or photographic recording of the image.

The coronagraph is approximately 10' long and 1.5' across. The weight is 314 lbs.

Protocol

Photographs will be taken twice a day. They will be taken at a faster rate during times of limb activity. Each observing sequence will normally consist of four exposures: one unpolarized, and three at different polarization angles. This instrument may operate during unmanned phases of Skylab.

Data Return

Data recording is on 35 mm film.

Astronauts will retrieve the film from the center work station of the ATM canister during scheduled extravehicular activity periods.

APPENDIX VII

X-ray/UV Solar Photography, Experiment S020*

Principal Investigator: Dr. Richard Tousey
U. S. Naval Research Laboratory

Development Center: MSC

Integration Center: MSC

Contractor: Naval Research Laboratory, (Sub-contractor: Martin-Marietta Corporation)

Objectives

The objective of this experiment is to record on photographic film the detailed energy spectrum of x-ray and ultraviolet radiation from normal and explosive areas in the solar atmosphere. This instrument will primarily study weak emission lines of the solar emission spectrum from 10 to 200 Å, a region of the spectrum only partially covered by ATM instruments.

Background

The solar corona and chromosphere can act as a high temperature laboratory providing clues to atomic and plasma processes unavailable elsewhere. The 10 to 200 Å region is rich in emission lines of highly ionized atoms. Many of these emission lines are weak and require instruments of high sensitivity for their observation. S020 will make these observations by taking advantage of the long exposure times and film return capability of the manned Skylab spacecraft.

Hardware

The S020 spectrograph is sensitive over the x-ray and extreme ultraviolet range (10-200 Å). Sunlight, entering a narrow slit, is diffracted into its different energies by a

*In addition to the solar physics experiments mounted in the ATM, one experiment covering the x-ray and ultraviolet regions will be performed from the scientific airlock. This is a description of the S020 experiment.

concave grating which is mounted at a grazing angle of incidence to the light beam. The intensity can be determined to an accuracy of 10% and energy differences corresponding to a wavelength separation of .05 Å can be resolved. Filters of thin metallic films, transparent to x-rays, are placed in front of the entrance slit to block undesired ultraviolet and visible light which could fog the film.

The instrument is mounted in an airlock in the Skylab wall facing the sun; this being the only solar experiment which is not mounted in the ATM module. The film strips are mounted in cassettes which are attached to the back of the instrument. A finder telescope enables an astronaut to center the slit on the area of the sun to be studied. The spectrograph weighs about 70 lbs. and has a rectangular shape approximately 8" x 8" x 18".

Protocol

The astronaut places the spectrograph in the airlock and aligns the slit with the ATM towards the sun in cooperation with a second astronaut. He then takes a sequence of exposures of up to one hour durations.

Exposures are taken several times during the Skylab mission. During periods of activity on the sun, a "flare watch" is maintained with an astronaut on standby alert. When a flare occurs several exposures are taken from the initial onset to the decline.

Data Return

The exposed film is to be returned to the earth for development.

CHAPTER FOUR

EARTH OBSERVATIONS

EXPERIMENT PROGRAM BACKGROUND

Rationale

Remote sensing of the Earth from orbital altitudes has the potential of yielding information which is of fundamental importance for effective use and conservation of natural resources in both underdeveloped and technologically advanced nations.

Photography from orbital altitudes in the visible and near-infrared spectral regions has already proven to be invaluable for standard synoptic mapping of geographic features over large areas. Systematic use of multispectral remote sensing techniques over an extensive wavelength region has the potential of greatly extending the scope of this capability to include mapping of terrestrial resources and land uses on a global scale. For example, resources amenable to study are: crop and forestry cover; health state of vegetation; types of soil; water storage in snow pack; surface or near-surface mineral deposits; sea-surface temperature; and the location of likely feeding areas for fish. Comprehensive surveys of such resources will help manage developing world-wide problems of such accelerating urgency as food supplies, mineral shortages, energy needs, environment pollution and expansion of human settlements.

It is imperative to note that many of the environmental features requiring study are in remote regions of the earth and are highly variable in time. Space systems can, therefore, offer the following distinct advantages over conventional aircraft: (1) a broad field of view afforded by the increased altitude; (2) periodic coverage of the same area, and (3) coverage of remote areas otherwise not easily accessible.

History

Meteorological satellites have been used since the beginning of the space program to provide additional meteorological data for better weather forecasting and timely warning against life-threatening atmospheric disturbances. Examples are the Nimbus, Tiros and ATS satellites equipped with visible and infrared sensors.

The first unmanned satellite designed exclusively for Earth Resources surveys is planned for launch in 1972. It is designated ERTS-A (Earth Resources Technology Satellite) and carries instrumentation covering the visible and near-infrared spectral regions. Ground resolution is slightly lower than that of comparable instruments on Skylab.

Development/testing of remote sensing techniques and interpretation/correlation of instrument response over a given target with the known characteristics (ground truths) of that target are part of NASA's aircraft program. This program is centered at MSC and presently includes three aircraft of different operating characteristics. They conduct aerial reconnaissance of ground truth sites from altitudes ranging up to 60,000 ft. to test measuring equipment, validate interpretive techniques and ascertain the dependability of recognizable spectral signatures. Development has reached the point where remote sensing techniques have been used operationally to assist, for example, in such problems as pin-pointing forest fires through dense smoke cover and mapping corn blight damage.

Some exploratory tests of remote sensing techniques have also been conducted from manned spacecraft during Gemini and Apollo missions. Several thousand earth pictures of high quality obtained by the Gemini crew have been widely distributed to potential users and effectively used in many disciplines. Apollo afforded the opportunity for extending the photographic techniques over and beyond those employed in Gemini. Significant advances involved the addition of haze filters; multiband photography in the visible and near-infrared wavelength regions; overlap photography for stereo viewing; and photography of ground test sites.

ROLE OF SKYLAB

The Earth Resources Experiment Package (EREP) on Skylab will test and validate remote sensing techniques over a wide spectral region from orbital altitudes. Specifically, five experiments in the EREP will permit simultaneous remote sensing of ground truth sites in the visible, infrared and microwave spectral regions. These experiments are described in detail in the appendices.

These Skylab data will be correlated with information obtained simultaneously about the ground truth sites from aircraft and/or from <u>in situ</u> measurements. Particular emphasis will be placed on validating the utility of spectral signature identification from orbital altitudes. The importance of this procedure is that it would, for example, permit homogeneous fields of vegetation to be identified without the need for resolving individual plants. This mode of identification is highly desirable because it would greatly decrease the data load required for mapping earth resources (e.g., vegetation type, surface minerals, etc.) over extensive regions.

The microwave experiments are of particular interest since they represent the only all-weather system. This is because microwave radiation is not severely attenuated by cloud coverage and precipitation. It is of interest to note that the microwave experiments require an antenna too large to install on ERTS-A.

Men aboard Skylab will be used to acquire preselected primary or alternate targets, operate the equipment, minimize the collection of irrelevant data and investigate any necessary alternatives to the experiment protocol.

One of the primary goals in the Skylab development program is to identify user needs (local, state, federal and possibly foreign) and to structure the data gathering and analysis procedures to support these needs.

An opportunities document has been published outlining the EREP specifications and capabilities and requesting observational plans from interested user groups.

FUTURE DIRECTIONS

Satellite and aircraft systems will be used to complement each other for the development and operation of future systems for remote sensing of Earth Resources. Most of the initial testing and development, and the short-term high-resolution surveys over relatively small size target areas, will undoubtedly continue to be performed on aircraft. If a manned space shuttle becomes operational, then the testing and development of future space-based systems could advantageously be shifted to this vehicle for short-term orbital flights. On board the shuttle a test-bed facility should be available to make use of man's abilities in making impromptu changes in the experiment make-up and its operating procedures.

Operational systems for routine and long-term monitoring tasks generally will be performed from automated satellites.

APPENDIX I

Multispectral Photography Facility, Experiment S190

Principal Investigator: User group to be selected
(Project Scientist: Dr. J. Dornbach, MSC)

Development Center: MSC

Integration Center: MSFC

Contractor: Itek Corporation

Objectives

The Multispectral Photography Facility has been designed to photograph regions of the earth's surface and oceans in a range of wavelengths from the infrared through the visible. The facility consists of six cameras that photograph the same area at the same time. Because the cameras are accurately matched, the six separate photographs will have good registration with respect to one another; that is, all of the features seen in one photograph can be simultaneously aligned with the same features in the photographs from the other cameras.

Background

The advantage of multispectral photography is that various conditions of interest, such as soil moisture, types of vegetation, or health of the vegetation produce different spectral responses, or signatures. By studying features in various wavelength ranges, it is anticipated that information about such conditions can be deduced from the photographs.

Hardware

The facility has six cameras, which are precision bore-sighted, with lenses matched for focal length and distortion. The cameras are shuttered simultaneously. A total of 18 filters is included in the equipment.

A film vault is used for storage of the film when photographs are not being taken. The vault protects the film from radiation damage.

A control panel controls the taking of a picture sequence using astronaut-entered data. Various containers for filters, lenses and film magazines are provided to assist in the operation of the photographic facility.

The total weight of the camera and supplies is approximately 500 lbs. It occupies a volume of about 27 cu. ft.

Protocol

When the cameras are not in use, the film is stored in a vault designed to provide protection from radiation. The astronaut must move the film magazines from the vault to the cameras, install the magazine and check out the system. Specific commands for each picture sequence are transmitted from the earth. On the basis of these instructions, the astronaut controls and oversees the operations of the cameras. At the end of the picture taking sequences, the film is returned to the vault.

In addition, during some sequences, the astronaut himself will select the picture sequences on the basis of his observations. The view-finder from experiment S191 will be used for this purpose.

Photographic sequences will be executed on about 15 of the revolutions for each mission. Three or four sequences, totaling perhaps 1/2-hour duration, will be taken on each of the chosen revolutions.

Data Return

The primary data return is in the exposed emulsion. About 1200 pictures will be taken by each of the six cameras, for each of the three missions.

Four of the cameras will take black and white photographs in a specific wavelength region in the infrared or visible. The remaining two cameras will take color pictures, one in the visible and the other in the infrared. The color pictures have essentially the same data content as the black and white pictures, and serve as a cross check on the system.

Each frame covers an area of about 80 x 80 nautical miles on the surface. The resolution is approximately 100 ft.

APPENDIX II

Infrared Spectrometer, Experiment S191

Principal Investigator: User group to be selected
(Project Scientist: Dr. T. Barnett, MSC)

Development Center: MSC

Integration Center: MSFC

Contractor: Block Engineering Company

Objectives

The primary goal of Experiment S191 is to make a fundamental evaluation of the applicability and usefulness of sensing Earth Resources, from orbital altitudes, in the visible through near-infrared (i.e., 0.4 to 2.4μ) and in the far-infrared (i.e., 6.2 to 15.5μ) spectral regions.

Another specific and very important goal of experiment S191 is to use an astronaut for real-time identification of ground targets.

Background

Specifically, this instrument may permit quantitative correction for a major source of atmospheric attenuation, because remote spectral-radiance measurements made in the wavelength regions of strong water vapor absorption (e.g., ∿6.2-8μ) can be related to the atmospheric density profile of this absorbing gas.

The reliability of spectral signature identification from orbital altitudes will also be checked by comparing results made with concurrent measurements from aircraft and ground test sites. This technique has the potential of providing a means of monitoring from space the extent and health of surface vegetation, without the need for spatial resolution of individual plants. Geological information and precision sea-surface temperature measurements will also be obtained.

Although a similar instrument has been used to accumulate data from aircraft flights, the resolution and the contrast in the image are significantly different for remote sensing from orbital altitudes. It follows, therefore, that development tests from spacecraft are a vital extension to similar experiments which have been conducted from aircraft, because measurements from spacecraft have many advantages such as uniform lighting over vast areas and repetitive coverage.

Hardware

This instrument is known as a filter wedge spectrometer, and it will permit measurements of relatively high spectral resolution (e.g., from 1% to 4% in wavelength).

The maximum spatial resolution of the spectrometer will be 1 mrad, which corresponds to ground resolution of 0.235 nm (nautical miles) from a 235 nm orbit.

The launch weight and volume will be $\sim$ 420 lbs. and $\sim$ 12" x 12" x 40" respectively.

The infrared radiation detectors in the spectrometer must be cooled to 77° K, and this will be accomplished with a Malaker closed loop cooling system whose power requirements are in the 30-40 watt range. It uses helium gas in a refrigeration cycle.

Protocol

The spectrometer will have pointing and tracking capabilities within a cone $\sim$ ±20° about the nadir. The astronaut will use the view-finder/tracker to acquire the target which will be in his field of view for less than a minute. In acquiring the ground targets, the astronaut must maintain the 0.235 nm diameter resolution element within a target circle of $\sim$ 1 nm diameter for 1 sec. in order to permit one complete spectral scan. At the start of each spectral scan, the scene in the view-finder will be photographed with a small camera attached to the view-finder. Thus the astronaut effectively participates in the observation program. The astronaut will select secondary ground targets if the primary site is obscured by cloud cover, as well as other targets of opportunity as they become available.

Data Return

The primary data will be recorded on a magnetic tape unit along with data from other sensors in the EREP (Earth Resources Experiment Package). The magnetic tape and the film from the view-finder camera will be returned with each crew rotation.

APPENDIX III

Multispectral Scanner, Experiment S192

Principal Investigator: User group to be selected
(Project Scientist: Dr. C. L. Korb, MSC)

Development Center: MSC

Integration Center: MSFC

Contractor: Honeywell Radiation Center

Objectives

The primary goal of Experiment S192 is to assess the feasibility of multispectral techniques, developed in the aircraft program, for remote sensing of Earth Resources from space. Specifically, attempts will be made at spectral signature identification and mapping of ground truth targets in agriculture, forestry, geology, hydrology, and oceanography.

Background

The scanner will operate in 13 spectral bands from 0.4 to 12.5μ. These bands are relatively wide ($\sim$ from 0.05 to 2.3μ), and they are located in spectral regions with high atmospheric transmission.

Multispectral scanners have been flown in aircraft for several years. Promising results have been obtained for identification and mapping of vegetation and surface soils. Some progress has also been made in utilizing the remotely sensed data for assessing the health of vegetation.

Achievements in this area include crop identification, inventory, soil and geologic mapping based on unique signatures for certain crops in these bands. Airborne scanners have been used with automated computer discrimination techniques for areas as wide as 50 miles.

Hardware

The basic instrument design is that of an optical mechanical scanner utilizing an object plane nutating scan mirror, with a folded 12-inch reflecting telescope used as a radiation collector.

The 13 spectral bands in the visible and the infrared are 0.41-0.46, 0.46-0.51, 0.520-0.556, 0.565 0.609, 0.620-0.670, 0.680-0.762, 0.783-0.880, 0.980-1.08, 1.09-1.19, 1.20-1.30, 1.55-1.75, 2.10-2.35 and 10.2-12.5μ; and will have a ground resolution of 260 ft. by 260 ft. from an altitude of 235 nautical miles. The improvement in ground resolution over that for the IR Spectrometer (S191) is primarily due to the coarser spectral resolution of the scanner which permits a reasonable signal to noise ratio even with smaller field stops. The swath width in each scan will be 47 nautical miles, and the spacecraft motion will provide contiguous coverage.

The launch weight and volume are respectively ∿300 lbs. and ∿11.6 cu. ft. The maximum power requirement is ∿220 watts.

The thermal radiation detectors will require cooling to 77° K. This will be accomplished with a Malaker closed loop cooling system whose power requirements are in the 30-40 watt range.

Protocol

The spectral range covered by the scanner overlaps that for both the multispectral cameras (S190) and the IR Spectrometer (S191). This will permit a very useful cross check of results deduced from these three systems.

In addition, the IR Spectrometer data will hopefully provide atmospheric density profiles, which would be extremely useful for correcting the primary causes of atmospheric attenuation of the scanner data.

The astronaut can vastly increase the amount of useful data recorded by only taking data under relatively clear conditions and by limiting the data taken to areas of interest, including some highly instrumented test sites and also targets of opportunity. This can be done by using the view-finder for the infrared spectrometer (S191).

Data Return

The primary data will be recorded on a magnetic tape unit (∿72 lbs.) along with data from other sensors in the EREP (Earth Resources Experiment Package). The magnetic tape will be returned with each crew rotation.

Local, state, federal and international user participation for analyses of the accumulated data will be encouraged.

APPENDIX IV

Microwave Radiometer/Scatterometer, Experiment S193

Principal Investigator: User group to be selected
(Project Scientist: D. Evans, MSC)

Development Center: MSC

Integration Center: MSFC

Contractor: General Electric Company

Objectives

The objective of the experiment is the simultaneous measurement of the radar differential backscattering cross section and the passive microwave thermal emission of the land and ocean on a global scale.

Background

The Microwave Radiometer/Scatterometer complements the infrared spectrometer and multiband scanner experiments (S191 and S192) in extracting useful information about the characteristics of the earth surface and earth resources. For agricultural purposes, for instance, infrared remote sensing devices are very suitable in vegetation identification through the clear sky; however, it is most probable that clouds will exist in scattered areas in the sky and thus degrade the measurement results and interrupt the continuity of coverage. Effect of clouds on microwave propagation is less significant and in general can be accounted for by simultaneous use of microwaves of two appropriate frequencies.

The proposed microwave radiometer/scatterometer experiment is a combination of an active radar scatterometer and passive radiometer operating at 13.9 GHz. It is based on simultaneous measurements of radar differential backscattering cross-section and passive microwave thermal emission of the land and oceans on a global scale. The radar backscattering cross-section measurement gives a measure of the combined effect of the dielectric properties and roughness of the terrestrial surface whereas the passive microwave emission gives a measure of the combined effect of the dielectric properties, roughness, and brightness temperature of the terrestrial surface. The emissivity, i.e., a measure of the amount of energy of a certain frequency emitted in a certain direction from an object with certain dielectric properties and at certain temperature, is a function of the surface roughness of the body. Thus the microwave radiometer/scatterometer experiment can extract information about the roughness and temperature of the terrestrial surface, when the dielectric properties of the surface are known. The surface dielectric properties of the land vary a great deal according to its moisture content and the characteristics of vegetation and, therefore, to obtain the desired information over land coverage by the microwave radiometer/scatterometer experiment, "ground truth" at strategically selected sites must be supplied by other experimental means. Since the dielectric properties of oceans are essentially the same everywhere, the microwave radiometer/scatterometer experiment is most suitable for establishing global patterns of ocean surface roughness and brightness temperature. In turn the ocean surface roughness patterns can be related to ocean surface wind patterns which can be used to aid ship navigation and numerical weather prediction in oceanography and meteorology.

Radar ocean backscattering and radiometric measurements have been carried out extensively by aircraft which usually have high spatial resolution but limited coverage. Space-borne microwave radiometer/scatterometer measurements offer extensive coverage with useful resolution. The measurements made by NASA Earth Resources Aircraft Scatterometer Studies have led to the following conclusions:

1. Increasing wind speed and the related ocean surface wavelength result in increasing values of returned energy for all angles of incidence between 15 and 45 degrees.

2. The increases are substantial, as wind velocity increases.

3. The radar return is higher for upwind-downwind conditions than for crosswind conditions.

The space-borne microwave radiometer/scatterometer measurement results will be used to verify these aircraft findings and to establish the feasibility of determining patterns of ocean surface roughness and wind field on a global scale.

An altimeter experiment that shares the antenna assembly of the microwave radiometer/scatterometer experiment is also included in this experiment. The main purpose of the altimeter experiment is to obtain information about ocean state effects on transient pulse characteristics. Data will be used for future altimeter design for earth physics and geodetic studies.

Hardware

Major components consist of:

1. Transmitter for the microwave scatterometer
2. Receiver for the microwave radiometer/scatterometer
3. Transmitter for the altimeter
4. Receiver for the altimeter
5. Antenna assembly

The total assembly weight including antenna is about 260 lbs. and the total power consumption is about 150 watts.

Protocol

The mechanically scanned antenna sweeps the radar beam from left to right, across the earth's surface in a plane normal to the track of the spacecraft. The scan is not continuous and the beam moves in discrete steps from one cell to another, dwelling on each cell for a predetermined length of time. During this dwell time, the microwave instrument executes in time sequence two measurements: a passive radiometric thermal measurement with the transmitter turned off and an active scatterometer measurement with the transmitter turned on. Thus a paired measurement of apparent temperature and differential scattering cross-section are collected for each illuminated surface cell of about eight square miles. The scan period is chosen in accordance with the spacecraft velocity such that the surface cells are contiguous in the inflight direction.

Astronauts will assist in target identification, and operate and monitor equipment. Real-time communication between astronauts and the Mission Control Center will be required for discussion during the experiment. Ground truth information desired over test sites will be obtained by the NASA Earth Resources Aircraft scatterometer team for validation and extrapolation of space-borne measurements.

Data Return

All data will be recorded on magnetic tape and transmitted on one digitized channel at 250 bits/second.

APPENDIX V

L-Band Microwave Radiometer, Experiment S194

Principal Investigator: User group to be selected (Project Scientist: D. Evans, MSC)

Development Center: MSC

Integration Center: MSFC

Contractor: Airborne Instrument Laboratory

Objectives

The experimental objective is to supplement experiment S193 in measuring the brightness temperature of the earth's surface along the spacecraft track.

Background

The L-Band radiometer experiment is basically the same in operating principle as the radiometer part of the microwave radiometer/scatterometer experiment (S193) except the operating frequency is changed from 13.9 GHz to 1.42 GHz. The primary function of the experiment is to supplement the measurement results of Experiment S193 by taking into consideration the effect of clouds on radiometric measurements. By using two frequencies (S193 at 13.9 GHz and S194 at 1.42 GHz) simultaneously in measurements, corrections can be made on radiometric data to include the cloud effects.

The instruments to be used in this experiment are patterned after those which are being used on the NASA/MSC Earth Resources NP3A aircraft.

Hardware

Major components consist of:

1. Receiver assembly

2. Antenna assembly

The total weight of the system is about 75 lbs. and total power consumption is about 15 watts.

Protocol

The antenna, which always points in a local vertical direction, receives noise-like signals from the thermal emission of an earth surface cell and any intervening clouds being viewed along the spacecraft track. These signals are superimposed on the instrument system noise. The noise-like signal can be recognized and its mean value accurately determined if it is observed long enough to gain a measurable signal. The signal is compared with the measured mean value of another noise source with known temperature. The comparison constitutes the radiometric measurement and can be correlated to give a measure of the brightness temperature of the surface if dielectric properties and surface roughness are known.

When this experiment is carried out simultaneously with Experiment S193, the astronaut will be needed for equipment monitoring only.

Data Return

All data will be recorded on magnetic tapes. The data output is at 200 bits/second.

CHAPTER FIVE

ASTROPHYSICS

EXPERIMENT PROGRAM BACKGROUND

Rationale

The field of astronomy has undergone rapid development in the past few years. The birth of radio astronomy and the space program have opened up the entire spectrum of radiation and particles to observations. Many scientists from other fields, such as chemistry, biology, mathematics and especially physics, have developed an interest in space research. The result has been a sudden increase in the variety of studies and instruments which can be applied to investigating the problems of astronomy.

We would like to know whether or not the universe is infinite in extent. What circumstances are necessary for life to occur? What processes determine the life history of matter making up the solar system, stars, our galaxy and the universe as a whole?

The field of astronomy has traditionally been an area where the answers to fundamental questions have been sought and in which important conceptual discoveries have been made--the passage and measurement of time, the seasons, the size and shape of the earth, its place in the solar system and relationship with the rest of the observable universe. In addition, the study of matter in previously unknown states and of processes too exotic to occur naturally in our own environment--the generation of thermonuclear energy in the centers of stars, for example--have had a great influence on the growth of other physical sciences.

Until recently, progress in astronomy has been made by gradual theoretical and observational advances using instruments associated with ground based optical telescopes to measuring the sizes, spatial relationships, energy distribution and time changes of visible objects.

The increase in available information brought about by access to space and the opening up of the entire spectrum from gamma rays to radio waves holds out the promise of new insights into the questions we wish to resolve and discoveries of new phenomena, such as pulsars, previously hidden from our view.

History

With the advent of the sounding rocket program, following World War II, it became possible to send small payloads into space for a few minutes of observations. The rocket program continues to be a very effective way to make specialized astronomical observations in ultraviolet and X-ray wavelengths. Airborne experiments on balloons and high-altitude aircraft, have made observations of very high energy radiation and infrared, because the upper atmosphere is partially transparent to these radiations. Some astronomy experiments have flown piggyback on unmanned spacecraft such as OGO, OSO and Mariner, their scientific objectives being restricted by considerations of permissible size, weight and complexity. The OAO, and SAS spacecraft series are dedicated to ultraviolet and X-ray experiments of a more comprehensive nature.

Astronomy experiments have been carried on manned spacecraft in the Gemini and Apollo programs to take advantage of the presence of the astronaut and the opportunity for film return.

Unexpected sources of background illumination have been detected in the UV. Intense point sources and a diffuse background of X-rays have been discovered. Gamma ray and infra-red radiation have been detected coming from the center of our galaxy suggesting unusual processes taking place there. A number of other galaxies have been found to be unexpectedly bright in the UV and in the infra-red.

Different physical processes result in the emission of radiation characterized by the nature of the process and physical conditions at the source, such as temperature and composition. Usually the radiation is detectable across several spectral ranges, but it often is more noticeable in one than the other because of some unique feature recognizable above surrounding sky background. The spectral range in which the source is first detected may not be the only one or the one best suited for unraveling its properties. The discovery of pulsars in the radio range and the extension of their investigation into the visible and X-ray wavelength ranges has demonstrated the value of this total spectrum capability.

ROLE OF SKYLAB

Before large, elaborate space observatories are developed, the general characteristics of this new observing environment must be known. Ranges of intensities, background levels and the spectral properties of gamma ray, X-ray and ultraviolet sources must be evaluated. The Skylab facility will provide an opportunity to perform a variety of experiments of a survey nature with much longer observing time than available on rockets and with additional flexibility due to the presence of an astronaut. A less stringent weight limitation permits larger instruments to be flown and film and sample return provide better resolution data than could be obtained from an unmanned satellite. Seven astrophysical experiments on the Skylab will investigate two general areas besides the sun, which is to be observed using the ATM and experiment S020.

The outer atmosphere of the earth and the interplanetary medium are studied by three experiments:

- UV Airglow Horizon Photography (S063)
- Gegenschein/ Zodiacal Light (S073)
- Particle Collection (S149)

Objects external to the solar system are studied by four experiments:

- Nuclear Emulsion (S009)
- UV Stellar Astronomy (S019)
- Galactic X-ray Mapping (S150)
- UV Panorama (S183)

The Gegenschein/Zodiacal Light and Particle Collection experiments both study the characteristics of the interplanetary medium; the former by viewing the sunlight scattered off the dust in the solar system, the latter by studying the impact of the dust particles themselves on prepared surfaces. The dust particles are believed to be vestiges of primordial solid material in the asteroid belt which has been pulverized by many collisions down to microscopic debris. Drawn toward the sun by gravity and blown outward by the pressure of sunlight and the solar wind, they orbit the sun, between the planets. They are not only a potential hazard to space travel and a source of interference with observation of faint objects outside the solar system, but, potentially, carriers of information about the conditions under which the solar system was formed.

The UV Stellar Astronomy, UV Panorama and Galactic X-ray Mapping experiments are intended to provide a comprehensive survey of the sky in their respective spectral ranges. Their objectives are to determine the intensities, spectral energy distribution, and the locations of as many sources as possible; to provide a general appreciation of the factors influencing observations of these sources in space, such as interstellar absorption, background levels and the statistics of their positions; and to provide experience in making astronomical observations from manned spacecraft.

The two ultraviolet experiments differ in that the UV Panorama in designed to obtain lower resolution spectral information for more and fainter stars than the stellar astronomy study.

To date, all ultraviolet sources have been recognizable in visible light as stars, galaxies or nebulae. The X-ray sources are not usually recognizable in visible light and are so unusual that they are the subject of much speculation. The information obtained by the surveys will also provide additional insight into the physical conditions in these objects.

FUTURE DIRECTIONS

The Skylab experiments will contribute to identifying the advantages and disadvantages of man-attended space observations and obtaining information essential for planning future, more advanced instruments.

In optical astronomy, large telescopes, probably unmanned, will be required to provide very high resolution photographs and spectra and specialized investigations of very faint objects. Large, heavy spacecraft, such as the HEAO, will be required to extend gamma-ray and X-ray surveys to fainter limiting magnitudes than can be detected by smaller, short-lived experiments. X-ray telescopes capabable of forming images will be needed to provide detailed views and high resolution spectra of the sources.

The Skylab experiments will help in laying the necessary groundwork for these projects.

APPENDIX I

Nuclear Emulsion, Experiment S009

Principal Investigator: Dr. Maurice Shapiro, Naval Research Laboratory

Development Center: MSFC

Integration Center: MSFC

Contractor: NRL

Objectives

The objective of this experiment is to record the cosmic ray flux incident outside the earth's atmosphere, especially the relative abundance and energy spectrum of heavy nuclei.

Background

Cosmic rays were first discovered in 1912. They consist of the nuclei of the chemical elements having extremely high kinetic energies which impinge on the earth's atmosphere from outer space.

The incident flux of cosmic ray primaries is very small, $\sim 1/2$ per second per cm^2, but interactions with the gases in the earth's atmosphere produces showers of particles.

Most of what is known about cosmic rays has been obtained from nuclear emulsion stacks exposed for several hours (~ 10) on high altitude balloons. Theories of nucleogenesis predict the relative abundance of nuclei that would be produced in the thermonuclear reactions occuring in possible sources such as neutron stars. It is there fore of great interest to study the relative abundance of the nuclei reaching the earth. Interaction with gases in the upper atmosphere however, has the effect of breaking up some of the primary nuclei thereby distorting the charge spectrum of particles as measured form a balloon. To obtain as accurate a measure as possible of the relative abundance of various nuclei in the primary cosmic ray flux, experiments must be carried into space.

A nuclear emulsion experiment conducted on a Gemini flight measured the abundance of light nuclei $Z<10$. The Skylab nuclear emulsion experiment will provide a long exposure to determine the abundance and energy spectrum of the heavy nuclei (Z between about 15 and 30). The abundant iron nucleus (Z=26) is in this range.

Hardware

The instrument consists of two adjacent stacks of nuclear emulsion strips. This emulsion differs from regular photographic emulsion being considerably thicker and containing a much higher density of grain material to improve the detection of tracks left by charged particles. The stacks are hinged together like the two sides of an open book and contain several layers of different emulsion types.

The emulsion stacks are mounted inside the Skylab Multiple Docking Adapter, separated from space by a thin section of the spacecraft wall. During exposure the "book" is open, allowing high energy particles which have passed through the wall to enter the front surface of both emulsion stacks. The wall thickness, 1/8" of aluminum, is equivalent to 1/2 gm/cm^2, whereas balloons cannot reach less than $\sim$3 gms/cm^2 of atmospheric thickness. The experiment weighs about 75 pounds, 45 of which is housing, and its volume is less than a cubic foot.

Protocol

The astronaut periodically adjusts the direction towards which the film surface is pointed, during exposure, throughout the entire first manned visit, to insure that only those particles coming from outer space are recorded and that those scattered up after collisions with the earth's outer atmosphere are excluded.

A timer automatically closes the "book" whenever the Skylab's orbital position is inside the South Atlantic Anomaly, where the Van Allen belts dip closer to the earth, or at high latitudes where the earth's magnetic field points downward, and unwanted particles are permitted to penetrate down to the Skylab's orbital altitude. The total exposure will be about 240 hours.

Data Return

The exposed emulsion will be returned to the earth and peeled apart in thin strips which are numbered, developed and scanned for tracks. By measuring the variations in thickness and direction of the tracks and tracing their entire path through the strips, the energy and charge of the cosmic rays can be determined.

From the numbers of particles recorded at each value of energy and charge, the abundance ratio of particular nuclei, and the difference in abundance of even and odd Z, one can learn something about the physical conditions where the nuclei were formed, the time that has elapsed since they were formed, and the nature of their interactions with interstellar material in transit.

APPENDIX II

UV Stellar Astonomy, Experiment S019

Principal Investigator: Dr. Karl Henize, Northwestern Univ. and Manned Spacecraft Center

Development Center: MSC

Integration Center: MSFC

Contractors: Northwestern University (Subcontractors: Martin-Marietta Corp. and Boller & Chivens)

Objectives

The objectives of this experiment are to obtain ultraviolet line spectra of a large number of stars, ultraviolet photographs of the clouds and stars in the Milky Way and to gain experience in the techniques for doing astronomy from manned spacecraft.

Background

Since 1957, ultraviolet observations have been made by rocket and satellite experiments. For two years, the OAO-A2 has been providing ultraviolet pictures and spectra. Television pictures taken through different filters by the OAO-A2 Celescope instrument have showed the ultraviolet brightness of thousands of stars. The OAO also carried spectrophotometers which have recorded the ultraviolet energy distribution of several hundred objects--planets, stars and galaxies--with a resolution of about 1Å.

The Skylab instrument is a spectrograph designed to obtain ultraviolet photographs of stars whose images have been spectrally dispersed. The spectrograph will have sufficiently high resolution to show atomic lines and the telescope is sufficiently large to record many faint stars in clusters and the Milky Way. It differs from the OAO in that it provides pictures with finer detail and better spectral resolution at the shorter wavelengths.

Hardware

The instrument consists of a reflecting telescope, a 35 mm camera and an additional moveable mirror. The total weight is 175 pounds, including storage container. The volume is approximately 4.5 cubic feet.

The telescope is mounted in an airlock in the side of the Skylab, with the moveable mirror extending beyond the outer wall of the spacecraft. The camera, containing film sensitive to ultraviolet light is attached to the back of the telescope inside the spacecraft. The telescope mirror is 6" in diameter and focuses a sky area 4° x 5° onto the film. A special prism can be inserted in front of the telescope to spread the light onto each color; a group of, say, six stars would then be recorded on the photograph as a group of six spectra.

The instrument is sensitive over the range of 1300-3000Å. Details as small as 20 arc seconds will be discernible. The resolution of the spectra is determined by which objective prism the astronaut employs--higher dispersion spreads the light over a larger area of film and spectra of only brighter stars are recorded. The resolution improves at shorter wavelengths being <10Å below 1700Å and <3Å below 1400Å.

The factor limiting the number of stars recorded and the resolution of the images is the motion of the Skylab itself. The blurring by motion restricts the length of exposures to a few minutes.

Protocol

The astronaut will place the telescope assembly in the airlock and point the external mirror to coordinates provided from the ground on the basis of the Skylab's current orientation. He will then locate, by eye, the particular sky area he wishes to record and initiate an exposure which may last as long as five minutes. The astronaut will record the time and duration of each exposure and comment on any conditions, such as small image motions which may occur, affecting the quality of the resulting picture. The inertia of the Skylab will ordinarily provide the pointing steadiness required.

He can take the photographs in the dark portion of any orbit during which the telescope is mounted in the airlock. Since this period of darkness lasts roughly 30 minutes, several pictures can be obtained in an orbit. Altogether, some 100-200 pictures will be taken of several dozen areas of the sky.

Data Return

The exposed film will be returned to the ground where it will be developed and analyzed. The spectra can be examined for discrepancies between theoretical spectra from model stellar atmospheres, for evidence of stellar chromospheres, and for the amount of interstellar extinction. The spectra of brighter galaxies can be obtained and compared. Background light levels due to zodiacal light and other sources can be sought. The experiment will provide a survey of sufficient scope to guide later more detailed astronomical observations.

APPENDIX III

UV Airglow Horizon Photography, S063

Principal Investigator: Dr. D. M. Packer, Naval Research Lab.

Development Center: MSC

Integration Center: MSFC

Contractor: NRL (Subcontractor: Martin-Marietta Corp.)

Objectives

The purpose of this experiment is to obtain visual and ultraviolet photographs of the night airglow and of the daytime ozone layer on a global scale.

Background

The behavior of ozone is an important factor in the thermal balance of the atmosphere. A world-wide network of ground stations also monitors the ozone concentration as a tracer for the physical properties and motions of the atmosphere.

Ozone, oxygen, nitrogen and a variety of other gaseous species in the earth's atmosphere are involved in a complex interplay of chemical reactions stimulated by the sun's radiation. Much of what is known of the earth's upper atmosphere has been obtained by observing the night and day airglow emitted during these reactions. Aurora are particularly bright emissions caused by the interaction of charged particles, guided by the earth's magnetic field, with the upper atmosphere.

Ozone and airglow observations have been made from the ground, aircraft, balloons and rockets. Only visible light can be seen from below, the ultraviolet light being absorbed by the lower atmosphere. Visible photographs of the airglow horizon have been taken from Gemini spacecraft and an ultraviolet camera will take long-range pictures during translunar coast on an Apollo mission.

The Skylab experiment will permit detailed studies to be made of the global variations in the photochemistry of the upper atmosphere in the ultraviolet light of the principal molecular spectral features.

Hardware

The experiment involves two 35 mm cameras with which an astronaut can take simultaneous pictures in visible and ultraviolet light. They are mounted on brackets at windows in the side of the Skylab. The ultraviolet camera has a special lens and window since regular glass absorbs ultraviolet light. Total weight, including storage container, is 100 pounds.

Protocol

The astronaut will aim the ultraviolet camera at an atmospheric feature, tracking it as he takes a photograph to compensate for the Skylab's motion across the earth's surface. Various filters will be attached to the lenses of both cameras to emphasize specific spectral features of molecules.

A dozen or more photographs will be taken on each of several daylight and nightside passes to record the ozone layer and night airglow respectively. Photographs of the twilight horizon will also be taken. Exposures of up to 20 seconds will be made with the astronaut identifying the target, time and duration of each. His commentary of interesting atmospheric phenomena, such as aurora, will be recorded as well.

Data Return

The exposed film will be returned and developed on the earth. The visible light photographs of atmospheric features, bodies of water, landmarks and clouds will be used to interpret the ultraviolet photographs.

These results will increase our understanding of the formation, distribution and movements of ozone and other gases and their chemical interactions in the upper atmosphere of the earth as well as on other planets.

APPENDIX IV

Gegenschein/Zodiacal Light, Experiment S073

Principal Investigator: Dr. J. L. Weinberg, Dudley Observatory

Development Center: MSFC

Integration Center: MSFC

Contractor: Dudley Observatory (Subcontractor: Martin-Marietta Corp.)

Objectives

The purpose of this experiment is to measure the brightness and polarization of the visible background of the sky as seen from the Skylab above the earth's atmosphere.

Background

Photographs and light level readings taken from the ground, rockets and satellites have not yet been sufficiently accurate to distinguish between models of the sources contributing to the faint visible background light of the sky outside the atmosphere. Hand-held photographs, taken from Gemini spacecraft, of the Gegenschein, or anti-solar enhancement, have established that it is extraterrestrial in origin rather than a phenomenon occurring in the earth's atmosphere. An Apollo lunar orbit experiment will attempt to photograph the Gegenschein from the dark side of the lunar orbit to determine by triangulation whether or not it is due to a "zero phase" enhancement of sunlight scattered off the interplanetary medium or a cloud of dust maintained in the gravitational null point one million miles from the earth, opposite the sun. The Skylab study will be a complete survey of the sky from above the variable interference of visible airglow emission and atmospheric extinction.

Hardware

The instrument consists of a camera and a small telescope. These are extended into space through an airlock in the wall of the Skylab. The telescope has a photometer which measures the sky background light levels through several filters.

It is sensitive enough to record light levels as faint as 7th magnitude stars in its field of view.

The telescope and photometer are also used for the T027 contamination experiment. Total weight (including T027) is 270 pounds.

Protocol

The astronaut places the telescope and camera in the airlock and extends them out into space. He then activates a mechanism enabling the telescope to perform scans of the sky automatically. The camera records the field of view being scanned by the telescope. The light level readings from the photometer are recorded on magnetic tape together with coordinates of the area of the sky being measured.

Data Return

The tapes and film are returned to the ground where they are analyzed. After subtracting the signal caused by stars in the telescope field of view, the photographs and light level readings are combined to make a map of the background brightness of the sky.

By comparing the amount of light at different colors and polarizations with the spectrum of the sun one can indirectly obtain information about the sizes, shapes, composition and numbers of the dust particles traveling in interplanetry space which reflect the sunlight and produce the zodiacal light. In addition, the variation of the brightness relative to the direction of the sun and the ecliptic plane will enable the interplanetary contribution to background light level to be distinquished from the interstellar background and any contribution from a hypothetical dust cloud associated with the earth and moon.

APPENDIX V

Particle Collection, S149

Principal Investigator: Dr. Curtis Hemenway, Dudley Observatory

Development Center: MSC

Integration Center: MSFC

Contractor: Dudley Observatory

Objectives

The purpose of this experiment is to collect material from interplanetary dust particles on prepared surfaces suitable for studying their impact phenomena.

Background

Prepared surfaces, flown on rockets and satellites have not yet recorded impact craters which have unambiguously been identified as having been caused by the interplanetary dust particles impinging on the earth's outer atmosphere. Surfaces flown on Gemini spacecraft suffered from contamination. The Skylab experiment provides a long exposure for several types of surfaces.

Hardware

The instrument enables sets of extremely smooth plates and thin metal films to be exposed to space though an airlock in the wall of the Skylab. The plates are made of metal, plastic and glass with highly polished surfaces. They are manufactured and sealed in cassettes under the cleanest conditions possible. Each is pre-scanned microscopically and all scratches, dust and surface imperfections are cataloged. To make the identification of these features easier, a gold film is first evaporated onto the plates from a grazing angle. This produces "shadows" behind any specks or pits on the surface, making them stand out in relief. The thin metal films are pre-scanned for pinholes.

Several plates, each roughly 6" square, and films, are mounted in a re-sealable cassette which is in turn mounted in a motorized support unit. This unit is extended out through the airlock where it opens and closes the cassettes by remote control. Some surfaces are not exposed and act as controls. The total unit weighs about 100 pounds.

Protocol

The astronaut places the instrument in the airlock and exposes the plates for several days when the Skylab is manned. In the periods between manned visits, plates are left exposed for up to two months, the cassette being opened from the ground to prevent contamination by the thruster exhausts during arrival and departure of the CSM.

Data Return

After exposure, the plates and films are re-sealed in the cassette which is retracted into the Skylab. The cassettes are returned to the ground where they are opened and the special surfaces are again scanned microscopically for new craters or punctures left from the impact of interplanetary dust particles. Shadowing at a different angle is used to aid in this search. The thin films are scanned for evidence of penetrations.

From the size, shape and number of these impact features, it is possible to obtain information about the masses and speeds of dust particles as well as the number per unit volume of space. Possibly something about their composition can be determined by probing for minute chemical traces of the particle material which may remain embedded in the bottom of the impact crater.

In addition to providing information about the characteristics of the interplanetary dust, the results of this study will help to better define the hazard to space travel posed by dust particle penetration.

APPENDIX VI

Galactic X-Ray Mapping, S150

Principal Investigator: Dr. William Kraushaar, University of Wisconsin

Development Center: MSFC

Integration Center: MSFC

Contractor: University of Wisconsin (Subcontractor: Spacecraft Inc.)

Objectives

The purpose of this experiment is to conduct a survey of the sky for faint x-ray sources.

Background

X-radiation has been observed from more than 40 stellar sources over the past 10 years. Most of these studies have been conducted using rockets in the energy region from 1-10 KeV; however these rockets have a viewing time of only 3 minutes. Satellites such as SAS-A, launched December 1970, will complete the survey of stellar sources in the 1-10 KeV region. The Skylab experiment provides a sky survey in the 0.2-12 KeV energy range.

Hardware

The instrument consists of a set of proportional counters which will cover the spectral region from .2 to 12 KeV. It is physically mounted on the launch vehicle. Accordingly, the life time of the experiment is limited to 4-5 hours. During this time detectors with a 20° field of view will determine the location of X-ray sources to within 20 arc minutes. Only about 1/2 of the sky will be viewed, however. Due to daylight X-ray fluorescence, no data below .7 KeV will be available during the day time half of the orbit. The detectors, electronics package and gas supply, which amount to about 4 cubic feet, weigh a total of 257 pounds.

Protocol

The experiment, mounted in the S-IVB, will be launched in the manned phase of the Skylab sequence. After separation at 120 nm the S-IVB will remain in the 120 nm orbit and data taking should commence 2-3 hours after launch. The experiment is, therefore, operated unmanned.

Data Return

Data will be recorded and transmitted back by telemetry. Spectra will have energy resolution of 50% at 1/2 KeV and 10% at 10 KeV.

Because most x-ray sources are not recognizable from the ground in visible light, it is necessary to develop a catalog listing the precise position of as many sources as possible, to guide later, more detailed studies. The results of the Skylab survey will provide a catalog of faint x-ray (.2-12 KeV) sources including their strength and spectral characteristics.

APPENDIX VII

UV Panorama, S183

Principal Investigator: Dr. Georges Courtes, National Scientific Research Center (CRNS), France

Development Center: MSFC

Integration Center: MSFC

Contractor: CRNS, France

Objectives

The purpose of this experiment is to measure the ultraviolet brightness of a large number of stars.

Background

Rocket experiments have obtained high resolution spectra of individual bright stars and the OAO-A2 telescope has obtained images of many star fields in four spectral bands.

The Skylab experiment will provide a photographic survey in two bands with fine spatial and photometric resolution of a number of star fields previously unavailable.

Hardware

The instrument consists of a telescope and uses the same movable mirror as S019. Total weight is about 150 pounds. The telescope is mounted in an airlock in the wall of the Skylab with the moveable mirror extending outward to permit viewing in different directions.

The telescope includes a grating spectrograph which collects the ultraviolet light from the spectrum of a star in its field of view into two 600 Å wide bands centered at 1800 Å and 3000 Å. The light is imaged onto film as two dots, each dot representing the light in the respective band. A group of stars in the field of view would thus be recorded as a group of dot pairs. Stars as faint as 7th magnitude can be recorded with 7 arc minutes of angular resolution over a 7° x 9° field of view.

The spectrograph is designed to permit very long exposures through the use of a mosaic of lenses which prevents image motion (due to variations in spacecraft pointing) from obliterating the spectral information contained in the dots. A separate camera can replace the telescope to record photographs of stars in a third ultraviolet band centered at 2500 Å.

Protocol

The astronaut places either the telescope or camera in the airlock. Using coordinates provided from the ground, he points the movable, external mirror toward a particular area of the sky. Sighting with a viewing eyepiece, he centers the field of view and makes a sequence of exposures up to 20 minutes in duration, taking up to 70 exposures in a single manned visit to the Skylab.

Data Return

The photographs are returned to the earth for processing. From the film images, the amount of light emitted by stars in the two ultraviolet bands can be determined. These values can be compared with theoretical ultraviolet spectra and the spectra of brighter stars obtained by OAO and the S019 experiment to determine average ultraviolet colors of differences between stars of the same type. In addition, the variation with wavelength of observation of distant stars due to interstellar dust can be used to study the distribution and composition of this dust. The overall average ultraviolet color of a group of stars such as a cluster or a galaxy will be compared with the visible color for unexpected discrepancies.

CHAPTER SIX

ENGINEERING AND TECHNOLOGY EXPERIMENTS

EXPERIMENT PROGRAM BACKGROUND

Rationale

This chapter contains a number of experiments which do not conveniently fall into the other disciplinary frameworks. It is useful to consider these experiments within the following context of space experimentation:

1. Zero-g Systems Studies

A number of the experiments are particularly oriented toward the interaction of man with his new zero-gravity environment. In this category we can consider

a. Habitability and Crew Quarters, M487

b. Astronaut Maneuvering Equipment, M509

c. Foot-Controlled Maneuvering Unit, T020

d. Crew/Vehicle Disturbance, T013

e. Manual Navigation Sightings (B), T002

The Astronaut Maneuvering experiments (M509 and T020) are closely allied. They investigate two different techniques for future use by man for extravehicular activity (EVA). In the Skylab program, these maneuvering units will be operated inside the SWS working volume.

2. Spacecraft Environment

Several experiments are designed to study the spacecraft environment, both natural and induced:

a. Radiation in Spacecraft, D008

b. Inflight Aerosol Analysis, T003

c. Coronagraph Contamination Measurement, T025

d. Contamination Measurements, T027

e. Thermal Control Coatings, M415

f. Thermal Control Coatings, D024

g. Expandable Airlock Technology (B), D021

The two thermal control coating experiments are complementary, not redundant. The M415 experiment investigates the effect of the launch environment -- earth's atmosphere, retro rockets, etc. -- on spacecraft surfaces. The D024 experiment investigates the long-term effects of the space environment, particularly sunlight, on spacecraft surfaces. "Contamination" concerns any effects of spacecraft effluents on astronomical and Earth-looking experiments, and it is discussed in detail in Appendix VIII.

3. Other Experiments

Of the remaining experiments, one (T018) is passive, and located only on the launch vehicle, while the other two depend very strongly upon man to operate them in space:

a. Materials Processing in Space, M512

b. Zero Gravity Flammability, M479

c. Precision Optical Tracking, T018

Experiments M512 and M479, which both share a common vacuum facility, are our first investigations into basic physics and chemistry in space. It is hoped that such research will lead to practical use of space for processing of a variety of materials, from crystals to pharmaceuticals.

History

The Background for these experiments is discussed in each appendix.

ROLE OF SKYLAB

With the exception of T018 and M415, all these experiments depend critically on the involvement of man in the Skylab Program for their successful accomplishment.

Some, e.g., D024, use man only in the role of a data-retriever. However, the majority of these experiments have no relevance or could not be accomplished without the presence of man. All of the zero-g systems experiments are intimately involved with men in orbit. The Radiation in Spacecraft (D008) and Inflight Aerosol Analysis (T003) experiments are of interest only as they relate to man in space.

The contamination experiments (T025 and T027) and the Crew-Vehicle Disturbance experiment (T013) investigate the impact of man on his environment and on his spacecraft.

FUTURE DIRECTIONS

These experiments will provide data which is very important in the development of future earth orbital space stations for the conduct of scientific experimentation. Through the Skylab program, we will have a better understanding of how man performs in space, what tools he needs to accomplish his tasks, and what his influence is on the space environment.

APPENDIX I

Habitability/Crew Quarters, M487

Principal Investigator: C. C. Johnson, NASA/MSC

Development Center: MSFC

Integration Center: MSFC

Contractor: Martin-Marietta Corporation

Objectives

The objectives of this habitability study are to evaluate the features of the Skylab's living quarters, provisions, and support facilities that affect the crew's comfort, safety, and operational effectiveness.

Equipment, procedures, and habitat design criteria derived from one-g studies and previous short-duration flights may require modification for optimum support of long-duration missions. Systematic quantitative and qualitative observations will be made on the following aspects of system design and operations:

(a) Physical Environment -
(e.g., temperature, humidity, light, noise)

(b) Architecture -
(e.g., volume and layout of working and living areas)

(c) Mobility Aids and Personal Restraints -
(e.g., translation, worksite supports, sleep stations)

(d) Food and Water -
(e.g., storage, preparation, quality)

(e) Personal Garments -
(e.g., comfort, durability, design)

(f) Personal Hygiene -
(e.g., cleansing, grooming, collection and disposal of body wastes)

(g) Housekeeping -
(e.g., habitat cleansing, waste control and disposal)

(h) Communications -
(e.g., usage patterns, fidelity, comfort)

(i) Off-Duty Activities -
(e.g., exercise facilities, individual and group recreation, privacy features)

Background

This habitability evaluation is a multi-disciplinary set of systematic observations, and is not an experiment in the same sense as the other Skylab studies. It uses the facilities and activities planned for other mission objectives as its subject of study. The nature of this experiment is therefore essentially a test and validation of current design concepts, hardware features, and operational criteria.

Hardware

Specific inflight hardware in support of these habitability measures includes a portable humidity meter, sound level meter, air velocity meter, measuring tape, and thermometer. Their weight is 14.5 lbs. and volume 0.294 cubic ft.

The inflight cameras, lights, voice recorders and task equipment for M487 are the same as those supplied for the other assigned experiments and activities; additional ones are not needed. Film for M487 will be available from the M151 time-and-motion study and other documentation. Additional film for M487 will consist of 5 cassettes of S0168 16 mm. color film, weighing 1.0 lb. on SL-2, and 2.0 lbs. each on SL-3 and SL-4.

Ground support facilities include voice communication recording and inflight TV coverage, if taken. No special monitoring facilities are required.

Protocol

Crew participation in M487 is in three phases:

(1) Pre-flight: Astronaut training and baseline data are integrated with their training for the operational tasks and activity areas to be observed.

(2) Inflight: Normal usage of vehicle systems and facilities provides the test conditions for this study. Observations and data acquisition are integrated with the performance of these other activities. Total time is approximately 4 hours/mission.

(3) Postflight: Crew debriefing on subjective and technical comments.

This experiment will be performed on all three Skylab missions.

Data Return:

Primary inflight data will be obtained in three basic forms: written logs and checklists, voice tape comments, and motion picture films.

Real-time monitoring will not be required, but voice and TV telemetry will be available from the other activities and experiments integrated within this study. All M487 data will be evaluated postflight. The results will help in the identification of operational problem areas, assist in the planning and design of future crew quarters and personal equipment, and validate present ground-based design criteria and fidelity of one-g simulations and training methods.

APPENDIX II

Astronaut Maneuvering Equipment, Experiment M509

Principal Investigator: Major C. E. Whitsett/USAF
Air Force Space and Missile Systems Organization
Los Angeles, California

Development Center: MSC

Integration Center: MSFC

Contractor: Martin Marietta Corporation, Denver, Colorado

Objectives

To conduct an in-orbit verification of the utility of various maneuvering techniques to assist astronauts to perform tasks which are representative of future EVA requirements.

Background

The M509 experiment is a logical progression beyond the development of two maneuvering units for the Gemini program. These consisted of a handheld thruster unit and a multiple thruster backpack. The handheld unit was operated briefly during extravehicular activity (EVA) on two Gemini missions, but fuel depletion and unplanned time constraints precluded an adequate evaluation. The backpack was not operated.

In addition to technological advancements, M509 offers three major improvements over the Gemini maneuvering unit experiment. First, it will be conducted within the enclosed safety of the Skylab environment, second, there will be extensive and systematic data collection and reduction under laboratory conditions including correlation with preflight baseline simulation, and finally, there will be ample time scheduled for the experiment without the risks and constraints imposed by operational EVA.

The concept of powered astronaut maneuvering is fundamental to the development of an effective EVA capability which, in turn, is considered to be a major supporting element in the future of manned space flight. Specifically, NASA study of future manned space flight operational requirements has indicated that EVA can be expected to play a major role in such areas as space rescue, inspection and repair of parent and satellite spacecraft, personnel and cargo transport, and space structure erection. The addition of maneuvering aids to such EVA tasks is expected to reduce crew fatigue and stress, cut time requirements, offset pressure suit mobility limitations, and facilitate attitude orientation and stabilization.

Hardware

The astronaut maneuvering equipment of Experiment M509 consists of two jet-powered aids for maneuvering in a zero gravity space environment. These include a back-mounted hand-controlled unit teamed with the Automatically Stabilized Maneuvering Unit (ASMU), or backpack, and a hand-held maneuvering unit (HHMU). The backpack contains a rechargeable/ replaceable high pressure nitrogen propellant tank which supplies both units, and is therefore worn whether maneuvering by ASMU or HHMU. The electrical systems within the backpack are powered by a rechargeable/replaceable battery which, with the nitrogen tank, is shared with the Foot-Controlled Maneuvering Unit of Experiment T020. The astronaut dons the backpack over either a pressurized space suit or flight coveralls using a quick release harness similar to that used for parachutes.

The ASMU is maneuvered in six degrees of freedom (X, Y, and Z axis translation, and pitch, yaw, and roll) by means of 14 fixed thrusters located in various positions on the backpack. Control of the thrusters is imparted by two hand-controllers mounted on arms extending from the backpack. The controllers are identical to those used in the Apollo spacecraft. The left hand controls linear translation and the right hand, using an aircraft-type hand grip, controls pitch, yaw, and roll. There are three selectable modes of ASMU control: (1) DIRECT, whereby the appropriate rotation and translation thrusters are commanded in direct response to visual cues, (2) RATE GYRO, whereby an attitude hold feature and proportional rate commands are added to the DIRECT mode capability by means of rate gyro-sensed motions, and (3) CMG (Control Moment Gyro), whereby an attitude hold feature is added to the DIRECT mode capability by means of the momentum exchange caused by torquing an appropriate combination of pitch, yaw, or roll CMG's. In this mode, the momentum exchange rather than thruster firings causes attitude changes.

The HHMU is a simple, small, lightweight, completely manual device. The unit comprises a hand grip and controls for a pair of tractor thrusters and an opposing single pusher thruster; the assembly is connected to the ASMU propellant tank by a short hose. To orient and propel himself in any attitude or direction, the operator points the HHMU, aligns it to pass approximately through his c.g., and triggers the tractor or pusher thrusters as indicated by his visual cues.

Protocol

This experiment will examine the ASMU and HHMU maneuvering characteristics in a series of four test runs for each of three subjects. The test plan will exercise both the pilots and the equipment with such representative EVA-type functions as transfers across the workshop, station keeping, docking, tumble recovery, and simulated maintenance or scientific tasks. Three of the runs will be conducted with the operator wearing shirtsleeve clothing and one run will be made with the operator in a pressurized space suit. Since the maneuvering equipment of M509 will be compared with the Foot-Controlled Maneuvering Unit of Experiment T020, one and probably both of the T020 operators will also participate in M509.

Data Return

The ASMU is instrumented to record numerous significant engineering data points including pertinent information on the HHMU and biomedical data during the pressure-suited runs. This data is sensed, collected, and telemetered from the free-flying ASMU to a receiver within the orbital workshop and together with recorded voice commentary, is later dumped via external telemetry to ground stations. Additional experiment data will be provided by in-flight television, post-flight still and motion picture data, and logbook entries.

It is expected that M509 will provide a wide range of valuable information on maneuvering unit handling qualities, operating techniques, consumable requirements, capabilities, and limitations.

The correlation of in-flight data with pre-flight and post-flight ground simulation will constitute a major factor in determining the applicability, fidelity, capabilities and limitations of various ground simulation techniques.

APPENDIX III

Foot-Controlled Maneuvering Unit, Experiment T020

Principal Investigator: Mr. Donald Hewes
Langley Research Center

Development Center: LaRC

Integration Center: MSFC

Contractor: Martin Marietta Corporation, Denver, Colorado

Objectives

To evaluate the ability of the astronauts to use the Foot-Controlled Maneuvering Unit (FCMU) for: (1) Attitude Control, (2) Gross Maneuvering, (3) Precise Maneuvering.

To compare this system with stabilized and unstabilized systems of M509 in flight and on simulators.

To correlate the flight experiment with ground simulators.

Background

Extravehicular activity (EVA) has been recognized as a major supporting element of future manned space flight in terms of such functions as space rescue, space vehicle inspection and maintenance, personnel and cargo transport, and space structure erection. The addition of powered maneuvering aids to such EVA tasks would reduce crew fatigue and stress, cut time requirements, offset pressure suit mobility limitations, and facilitate attitude orientation and stabilization. The FCMU represents a simple, reliable, compact vehicle for examining the dynamics of a hands-free EVA maneuvering within the safe confines of the orbital workshop.

Hardware

The FCMU is a research vehicle for examining the maneuvering dynamics of a cold gas jet-powered personal propulsion system in a zero gravity space environment. It comprises a saddle-mounted structure at the base of which is a cross member containing a pair of foot pedal controls and outboard of them, a pair of quadruple thruster assemblies. The FCMU is propelled by high pressure nitrogen supplied from a back-mounted tank. The operator, wearing either a pressurized space suit or flight coveralls, controls pitch, yaw, roll, and translation along his head/foot axis through a combination of left and right, up and down, toe and foot commands.

Both the FCMU propellant tank and battery are rechargeable/replaceable units, which are shared with the astronaut maneuvering equipment of Experiment M509.

Protocol

This experiment will examine the maneuvering characteristics of the FCMU using two test subjects in a series of runs which will include both shirtsleeve and pressure suited operations. Additionally, the experiment will study the trade-offs between the maneuvering limitations inherent in the four degree-of-freedom FCMU (versus six for M509) and its advantages of simplicity, light weight, low cost, and hands-free operation. Of prime significance will be the ability of the astronaut to master the skills and coordination necessary to make the FCMU approach reasonably competitive with, or complementary to, the hand-controlled, stabilized backpack maneuvering concept of Experiment M509.

Data Return

The principal data collection is accomplished by two motion picture cameras, one mounted in the workshop dome and a battery-powered, forward-looking camera mounted within the FCMU frame. Additional data is supplied by recorded voice commentary and logbook entries. Since the FCMU will be compared with the maneuvering equipment of M509, one and probably both of the test subjects will also participate in Experiment M509.

It is expected that the information derived from this experiment will add valuable engineering inputs into future maneuvering unit design. Further, the correlation of in-flight results with pre-flight baseline simulation will provide necessary feedback into and assessment of the various simulation techniques in terms of applicability, fidelity, capabilities, and limitations.

APPENDIX IV

Crew/Vehicle Disturbances, Experiment T013

Principal Investigator: Bruce A. Conway, LaRC

Development Center: LaRC

Integration Center: MSFC

Contractor: Martin Marietta Corporation, Denver, Colorado

Objectives

The objectives of this experiment are:

1. To measure and record in zero-g, using typical crew activity in a space vehicle, data on astronaut limb motion, astronaut position, astronaut-induced forces and moments on the spacecraft, and simultaneous vehicle attitude perturbations.

2. To verify an existing analytical technique developed to predict the effects of crew motion on spacecraft attitude.

3. To verify ground-based simulation program data on crew-motion induced vehicle attitude perturbations.

4. To evaluate the Skylab Apollo Telescope Mount (ATM) Pointing Control System fine pointing stability.

Background

Many earth pointing and astronomy experiments for future manned spacecraft will require fine pointing stabilization ranging from fractions of an arcminute to fractions of an arc-second. Of the many disturbance phenomena that affect fine pointing those due to crew motion are dominant. Consequently, proper design of the fine pointing system requires accurate knowledge of crew motion disturbances. These disturbances have been studied on ground-based simulators and in zero-g experiments on aircraft. While these studies have provided valuable information, substantial uncertainties remain on crew motion in zero-g. Experiment T013 is designed to resolve these uncertainties and thereby provide system designers with accurate models of crew motion disturbances. At the same time, T013 will evaluate the fine pointing performance of the Apollo Telescope Mount, whose control system was designed using models of crew motion disturbances derived from ground-based simulations.

Hardware

The experiment hardware is:

1. Limb Motion Sensing System (LIMS) - a skeletal structure, incorporated into a suit, with pivots at the major joints of the body. Each pivot contains a linear potentiometer with outputs directly proportional to the degree of joint rotation. The LIMS provides continuous measurement of body limb position relative to the torso as the crewman performs the assigned tasks.

2. Data Cable - transmits the output of each LIMS transducer to the Experiment Data System (EDS) and the excitation voltage from the EDS to the LIMS transducers (or potentiometers).

3. Force Measuring System (FMS) - consists of two Force Measuring Units each of which has a sense plate, a base plate, a load cell array, load cell caging devices, a calibration mechanism, and a signal conditioner with associated wiring. The sense plate of FMU #1 contains foot restraints and may have provisions for engagement of a portable handhold.

4. Experiment Data System (EDS) - receives data from the LIMS sensors and the FMU signal conditioners. It conditions this data for recording on a vehicle instrumentation magnetic tape recorder for subsequent RF transmission to the ground.

5. Storage Container - houses the LIMS suit and the data cable.

In addition, the 16mm Data Acquisition Cameras will be used to record motions performed by the crewman.

Protocol

The experiment will be performed only once during the mission. It will be performed by one crewman, with assistance from the other two.

The total task performance time will be approximately 70 minutes.

The crewman performing the experiment will wear the LIMS. The outputs from the LIMS are transmitted in a data cable to the Experiment Data System (EDS). The crewman's center-of-mass and relative attitude will be recorded by photographing targets located on the crewman's suit. The film used will be returned in the Command Module (CM).

Forces and moments applied to the vehicle by the maneuvering crewman will be sensed by the FMS. In-flight calibration using a static load on each FMU will provide correction for any calibration shift occuring before or during experiment performance. Outputs from the FMS signal conditioners also will be routed to the EDS.

Data sent to the EDS will be recorded on magnetic tape for subsequent transmission to the ground by telemetry.

The crewman performing the experiment will be assisted in varying degrees by the other two crewmen; one of whom will read in sequence each task to be performed, announcing the beginning and completing of each with voice annotations as appropriate during task performance.

Forces and moments will be measured for a wide range of physical activity from events such as normal breathing, sneezing, and simulated control manipulations while restrained to one FMU, to free-soaring exercises from one FMU to the other.

Cluster attitude perturbations will be sensed by the Attitude and Pointing Control System and will be transmitted in real time by the ATM Instrumentation and Communication System.

Data Return

1. Film record of crew motions returned on CM.

2. Telemetry of the data recorded on the EDS.

3. Real time telemetry of the cluster attitude perturbations as sensed by the Attitude and Pointing Control System.

APPENDIX V

Manual Navigation Sightings (B), Experiment T002

Principal Investigator: R. Randle
Ames Research Center

Development Center: ARC

Integration Center: MSFC

Contractor: Kollsman Instrument Company

Objectives

To investigate the effects of the space flight environment (including long mission time) on the navigator's ability to take space navigation measurements through a spacecraft window using hand-held instruments.

Background

Previous data obtained with the use of simulators, aircraft, and the Gemini spacecraft has already demonstrated that man, in a space environment, can make accurate navigation measurements using simple hand-held instruments. This, together with already developed techniques for reducing the data to a position determination, means that a technique is available for man to navigate in space using simple instruments and without the aid of a computer. The intent of this experiment is to determine whether long mission duration appreciably affects the capability of man to obtain accurate measurements. Further, the experiment will return data which will be generally indicative of the effect of long duration space flight or man's capability to perform other precision tasks.

Hardware

The hardware for this experiment consists of two hand-held instruments, a sextant and a stadimeter. The sextant, which is quite similar to an aviator's sextant, will be used to measure the angles between two stars, and between single stars and the edge of the moon. The stadimeter, also an optical device, determines spacecraft altitude directly by measuring the apparent difference in elevation angle between a portion of the earth's horizon and its subtended chord.

Protocol

The sextant and stadimeter measurements will be made through the Multiple Docking Adapter windows. Although the necessary calculations to determine vehicle position and altitude could be made by the crew during the mission, this is not required as a part of this experiment. Earth-based radar tracking data will be used to determine the altitude and location of the vehicle at the time the on-board data are obtained. By comparing the ground based and on-board measurements, the accuracy of the on-board measurements can be determined. The accuracy data will be correlated and compared with data already gathered in simulators, high flying aircraft, and the Gemini spacecraft to determine the suitability of small, comparatively inexpensive, hand-held optical instruments for space navigation. In addition to the measurement data itself, comments by the astronauts on the operation of the experiment are expected to be a valuable part of the information returned.

Data Return

Data return will be in the form of logbook entries of the sextant and stadimeter readings. This will be supplemented as required by crew comments on the voice tape recorder.

APPENDIX VI

Radiation in Spacecraft, Experiment D008

Principal Investigator: Captain M. F. Schneider, AFWL, Kirtland AFB, New Mexico

Development Center: MSC

Integration Center: MSC

Contractor: AVCO Corporation

Objectives

The purpose of the experiment is to make radiation dose measurements in earth orbit. Such measurements are of importance in assessing the quality of dosimetry instrumentation for space application, in evaluating various analytical procedures that predict the radiation dose absorbed in earth orbit, and in providing data to study the biological reaction of man to such radiations.

Background

The major source of radiation in low earth orbit arises in the South Atlantic Anomaly, a region where, because of the particular shape of the earth's magnetic field, the Van Allen radiation belts are unusally close to earth. In other places, the radiation belts are comparatively weak below an altitude of, say, 300 nm.

For the orbit chosen for Skylab, significant radiation doses are accumulated only when the spacecraft passes through the South Atlantic Anomaly. In addition, however, there is a continuous background of radiation from cosmic ray sources. It is also possible that major solar flares occurring during the course of a mission will generate high energy protons and alpha particles, which will contribute to the radiation.

Hardware

The radiation in spacecraft experiment requires the following hardware:

1. 1 movable tissue-equivalent dosimeter. The sensitive element is connected by a 6-1/2 foot cable to its power supply and signal processing equipment.

2. 1 Linear Energy Transfer system (LET). The system consists of two solid state particle detectors and their associated electronics. The LET system provides data by which ranges (in tissue) of the incident particles can be determined.

3. 5 passive dosimeters. These dosimeters contain photographic emulsions and other materials sensitive to radiation. They integrate the dose received during the entire mission.

The total weight of the hardware is less than 8 lbs., and it occupies about 0.1 cu. ft. of space.

Protocol

The radiation in Spacecraft experiment will be flown on the first Skylab mission, SL 1/2.

The passive dosimeters are placed in specific locations in the CM and remain there for the course of the mission. Similarly, the LET system remains in a fixed position in the CM during the course of the mission. The tissue-equivalent dosimeter is normally stowed in a position near the LET system. Data from the LET and the tissue-equivalent dosimeter are recorded on the spacecraft data storage equipment for specified intervals of 45 minutes each during the course of the mission. It is expected that there will be six such intervals during each of 14 days of the mission. Five of these intervals will occur during consecutive passages through the South Atlantic Anomaly, and the sixth will take place at the highest northerly latitude of the orbit. Additional measurement intervals may be desirable if there is a major solar particle event during the mission.

During some of the measurement intervals, the astronaut will move the tissue-equivalent dosimeter to survey the radiation distribution in the spacecraft. The purpose is to determine the spatial distribution of the radiation and, by shielding the dosimeter with various parts of his body, to estimate the depth-dose relationship in the human body. The astronaut will maintain a log book in which he records the time and position of the dosimeter during the surveys. Two surveys will be made during passes through the South Atlantic Anomaly and two at the highest northerly latitude of the orbit.

Data Return

Data collected from the tissue-equivalent dosimeter and the LET system during the measurement intervals are stored on board the spacecraft and then returned to earth via telemetry. The data indicate the dose rate and the LET data on one second intervals during the measurement period. The log book of events during the radiation surveys is returned to earth at the conclusion of this mission.

The passive dosimeters are processed after return to earth. By comparison of the data among the various radiation sensitive materials, it is possible to determine the spectrum of the various types of particles producing radiation in the spacecraft. These data are the intensities integrated over the duration of the mission.

APPENDIX VII

Inflight Aerosol Analysis, Experiment T003

Principal Investigator: W. Z. Leavitt, DOT

Development Center: MSFC (Equipment was developed at ERC)

Integration Center: MSFC

Contractor: None

Objectives

Measure the sizes, concentration, and composition of particles in the atmosphere inside the Skylab as a function of time and location.

Background

This experiment, in an earlier version, was first proposed by Dr. Samuel Natelson of Michael Reeves Hospital, Chicago, Illinois, and submitted to the Manned Space Flight Experiment Board in the summer of 1964. It was assigned to the Apollo Program, but on occurrence of the fire on AS-204, it was postponed to AAP (now Skylab).

While the information it will generate is not mandatory for operations, it will serve several purposes. First, if the astronauts suffer any unexpected discomfort, either to their respiratory systems or skin, a correlation with particle presence could help account for it. Second, if there are unexpected or unusual problems with clogging of elements of the environment control system, appropriate particle data might help explain them. And third, even if there are no major problems in these areas, trends might be detected which would bear on crew or system performance on longer missions, and appropriate steps could be taken to obviate the occurrence of suspect particles.

Hardware

The experiment is self contained in an approximately 6" x 10" x 13" box with an air inlet, an air outlet, a filter selector knob, a channel indicator, and a particle-count readout register. The channel indicator reads "1", "2", or "3", and the register gives the corresponding concentration of particles in the 1.0 to 3.0 micron, 3.0 to 9.0 micron, and 9.0 to 100 micron ranges. The different settings of the filter are for the different locations where measurements are made. The filter is used to bring particles back for later identification and position correlation. Particle size and count are determined by passing a known volume of air through the measuring chamber and measuring the amount of light each particle scatters to a photodetector, and the number of light pulses, which corresponds to the number of particles. Total weight of the experiment and its carrier box is less than 9 pounds.

Protocol

The instrument is hand held by an astronaut at the desired point of measurement. Representative locations throughout the spacecraft are tested, such as the food preparation area, the personal hygiene area, and the crew quarters. Measurements at a main location are made thrice daily and take about 4 minutes each. Then, every ten days measurements are made at a number of additional predetermined stations and times; 10 more measurements any time, anywhere, can be made at the crew's discretion. Man's role is to move the instrument to its appropriate location as scheduled, hold it, set the filter, press the button, and read and log the outputs. At the end of the mission he also removes and stores the filter for return to earth.

Data Return

There will be two types of data: written log and returned filter. The former will be a record of particle count versus location and time, and the latter will provide a cumulative sample of the particles as a function of location.

APPENDIX VIII

CONTAMINATION MEASURMENTS

EXPERIMENT PROGRAM BACKGROUND

Rationale

In the design of complex spacecraft (S/C), interactions among different subsystems and components always have to be taken into account. Certain operations on S/C such as water dumps, thruster firings, etc., might interfere with scientific objectives of the other experiments. For example, bright ice crystals reflecting light into the camera might interfere with the study of the solar corona.

Many unmanned satellites and manned spacecraft have shown visible contamination of their optical surfaces in space. The Gemini and Apollo spacecraft showed significant window degradations and interference with star sightings after the water and urine dumps from the spacecraft. Thus it is a well recognized operational problem concerning the spacecraft technology. With increased sophistication, as we now look for fainter sources and also those in the x-ray, UV and infrared regions, we find that many spacecraft effluents become sources of possible interference. For long-term observations such as on space stations of the future, we must understand the nature and extent of these contamination sources and their backgrounds in many spectral ranges to operationally assure a clean environment for the experimenters on upcoming spacecraft. The problems concerning external contamination on spacecraft can be characterized by:

1. Deposition effects such as the thruster firing depositions and other effluent deposits on optical surfaces which may or may not disappear with time.

2. Atmospheric effects which result from leakages and dumps from the spacecraft and result in general increase in the background brightness around the spacecraft. These may also be time dependent.

In order to systematically study the effects of contaminants, we proceed with the general assumption that low light level astronomical and terrestrial observations will be carried out on future spacecraft including Apollo, Skylab and future stations. Physical considerations indicate that contamination is an experiment peculiar problem. For example, gaseous molecules might severely interfere with x-ray and UV region of observations but might contribute negligibly in the optical and infrared ranges. In general, the requirements for astronomy or earth observations are quite demanding so that conditions of optical surfaces and the atmospheres surrounding the S/C have to be monitored in order to interpret the experimental observations. The ideal situation occurs when the spacecraft optical surfaces and atmosphere are continuously monitored in real time to provide deposition and background data. Such an operational system is the goal for contamination measurements. Thus during peak contamination periods, certain control surfaces can be protected and those experiments can be operated safely which do not have interference from such contamination.

History

Although there were no planned contamination experiments on previous manned spacecraft, window sample and photographic analyses of water dumps in space have provided some useful information on the effluents surrounding the S/C. A careful selection procedure of materials control has been in effect which insists on various thermal and vacuum tests and on controlled environments for S/C components. For example, a careful selection of fuel for RCS thrusters can lead to reduced deposits on the S/C surfaces and prevent thermal control problems. Such ground-based studies are currently in progress in many NASA and other laboratories. Window seals have been evolved which do not evaporate complex molecules in the vacuum, which have deposited on the S/C windows in the past. But since the spectral regions are being expanded for observations in space and more accurate information is sought, we need to learn more about the problems so that experimental results are not limited due to contamination. Also, the decisions can be made regarding the attached or detached mode of experimental operations on future manned spacecraft only after the nature of contaminants is better understood. Thus it is clear that more space and ground based measurements are necessary to understand the deposition effects, effects due to water and urine and other ventings, and also their time varying effects for future observations from spacecraft.

ROLE OF SKYLAB

The Skylab signifies a very important level of sophistication in the manned space flight program. Feasibility of carrying out simple astronomy and earth observation studies have been demonstrated on Apollo and Gemini spacecraft. But with Skylab not only the duration of observations increases, but a rather significant investment has been made into the experiments in the above-mentioned areas, which require low light level observations. Some of the experiments on the Skylab itself are quite susceptible to contamination (e.g., White Light Coronagraph, S052). Additional data are also needed on deposition and degradation rates of optical surfaces, so that eventually real-time contamination monitors can be installed on the future spacecraft. This requirement is adequately reflected in the contamination measurement experiments assigned for the Skylab.

The contamination coronagraph experiment (T025) will measure light scattered by small particles both near and far from the spacecraft at small elongations while the photometer assigned to the contamination measurement experiment (T027) will do the same for larger elongation angles and in many wavelength regions. The sample array on T027 will provide information not only on accumulated total contaminants but the quartz crystal microbalances (QCM's) which are a part of this array will provide real-time contamination monitoring to detect depositions much less than a few micrograms/cm^2.

Put together, these experiments will not only give the gross contamination backgrounds for the ATM experiments, but will also provide real-time and total deposition rates on optical surfaces and will also record both photographically and photoelectrically any contaminant cloud surrounding the spacecraft. In the event that contamination cloud is found to be insignificant, other secondary objectives of the experiments can be met such as the spectrophotopolarimetry of the zodiacal light (interplanetary dust matter) near the sun and the photographic study of the nature and extent of the solar F-Corona Since this is a development approach, these sample exposure and coronagraph type of experiments are deployed through the scientific airlocks from the Skylab. These are described in the attachemnts.

FUTURE DIRECTIONS

Once the data from such measurements on Skylab become available, real-time monitoring devices for spacecraft environment and deposition can be developed and can then be provided as a part of housekeeping efforts aboard future space stations or experiment modules.

APPENDIX IX

Coronagraph Contamination Measurements, Experiment T025

Principal Investigator: Dr. George Bonner, MSC

Development Center: MSC

Integration Center: MSFC

Contractor: Martin-Marietta Corporation

Objectives

The primary objective of this experiment is to study the contaminant particulate atmosphere surrounding the S/C and to study the increase of such atmosphere with thruster firing, water dump, etc. A secondary scientific objective is to attempt photographs of the solar F-Corona if the surrounding atmosphere turns out to be negligible. Thus, this experiment attacks only one of the problems discussed earlier and is well suited for the study of bright particles which reflect sunlight.

Background

Apollo astronauts have visually reported the "fireflies" or ice crystals after water and urine dumps for up to 30 minutes or more after the completion of these dumps. Photographic records were made with a 16 mm movie camera on Apollo 9 from which some scientific information has been gathered such as the fact that the particle velocities are of the order of 10^4 cms/sec relative to the S/C and the particle sizes are in millimeters. Also ground-based telescopes have photographed the water dumps and other cryogen releases from the SIV-B Saturn rocket stage. However, more quantitative information is needed on the particulate atmosphere which will be provided by the coronagraph.

Hardware

This coronagraph consists of three occulting discs shaped from a single metal cylinder which has additional smaller rings to reflect any stray light away from the camera field of view. The discs are extended from the airlock.

The inside of the cylinder is threaded to reflect and trap any light reaching the back of the cavity. The camera field of view is 7° x 11° and it has a removable magazine so that the astronauts can observe gross visual contamination levels before opening the ATM experiments. The discs have diameters of about four inches (10 cm) and can be extended to about six feet from the airlock. The F-Corona can thus be studied beyond 1.75 degree up to which the ATM Coronagraph (S054) is designed to provide data. Thus this experiment will not duplicate the results of S054 but will supplement them. The elongation limit of T025 is 11 degrees.

The photometer used on the (T027) array will be used to measure brightness at elongations larger than 15° and thus will not duplicate this experiment.

The camera focus can be adjusted to photograph various volumes near the S/C at 4 ft., 20 ft., and at infinity to bring particles in these regions to focus and thus attempt to analyze different volumes surrounding the S/C. Even with a background scattered intensity of 10^{-8} solar brightness, a 6-micron diameter particle can be photographed at 4 ft. focus from the S/C.

The weight of the experiment is approximately 67 lbs. and the volume is 4.5 ft^3.

Protocol

The coronagraph will become operational in the earlier phase of the Skylab so that the view-finder can be used for visual examination of the contamination before the S054 solar experiment is opened. In addition, the experiment will be operated on the sunlit side during minimum venting activity, during thruster firings and during waste water dumps so that effects of these activities can be seen in the induced atmosphere. About 27 exposures per sequence are typically required for such data collection.

Manned interface includes variation of focus, visual examination through view-finder and centering of the sun behind the discs before taking the sequence of pictures.

Data Return

All data from this experiment will be on film. Total return weight will be approximately 20 lbs.

APPENDIX X

Contamination Measurements, Experiment T027

Principal Investigator: Dr. J. Muscari
Martin-Marietta Corporation

Development Center: MSFC

Integration Center: MSFC

Contractor: Martin-Marietta Corporation

Objectives

The main emphasis of this experiment is on the study of deposition of contamination on various optical surfaces under controlled conditions. This will be done in real time with the help of Quartz Crystal Microbalances (QCM) and integrated deposits will be analyzed upon the return of samples to the ground. Additional objective (in conjunction with the photometer for S073) is the photoelectric photometry and polarimetry of the sky at elongations longer than 15° from the sun to study the total brightness contributions from the contaminants illuminated by the sun. These contaminants will be studied in various wavelength bands using the photometer and filters which will help in their possible identification. The polarization measurements with the photometer system will help in determining the shape of the contaminating particles. In the shadow region the photometer system (S073) will be shared for zodiacal light studies. Thus T025 and T027 together give us sufficient information on the environment surrounding the S/C and on the rates of deposition of contamination on the optical surfaces without duplication.

Background

Deposition of contamination has been found on Gemini and Apollo windows on many flights, interfering with star sightings and lunar surface photography experiments; some sources of these depositions have been found to be thruster firings and molecular evaporations from the seals around the windows. Additional evidence of deposits greater than several micrograms/cm^2 has been found on the OGO-6 unmanned spacecraft.

However there have been no detailed postflight analyses of such deposits under controlled conditions in which reentry and environmental cross contaminations could be avoided. The sample array experiment attempts this.

Hardware

The total experiment weight will be about 50 lbs. and both the sample array and the photometer will be deployed outside the spacecraft with the help of a boom. Approximately 200 samples of 16 different types including 2 QCM's will be exposed from the scientific airlock and the array will be exposed for a total of 5 days during which the lengths of exposures of various groups of samples can be varied. The samples consist of window materials, mirrors, gratings, and other optical surfaces suitable for various wavelength regions. Careful engineering design assures minimal cross contamination between various samples which can be retracted in tight teflon sealed cells.

The QCM's are simple in principle and depend upon the measurement of the shift of the frequency of vibration of a quartz crystal when additional mass is deposited on its surface. Measurable frequency shifts correspond to depositions as small as 10^{-7} gms/cm^2 on the surface of the QCM. The QCM's have already been flight qualified and developed for this purpose. A scale shift amplifier is under consideration which would simply but effectively utilize the full dynamic range of the sensitivity of the instrument.

The photoelectric polarimeter photometer has a sun shield which allows it to measure brightness as close as 15° elongation from the sun. This photometer will be used for zodiacal light studies (S073) also. The spectral range of the filters is 4000-8200 Å and it has a rotating polarizer which helps in determining the shape of the particles and their light scattering properties. A 16 mm camera also takes simultaneous pictures. The photometer system has a 7° field of view.

The weight of assembly including the photometer (S073) is approximately 270 lbs. and the total volume is 16 ft.^{3}.

Protocol

The 5-day exposure is required to give enough data points for a typical 'daily' cycle of contamination around the spacecraft. An automatic programmer has been built to sequentially scan the sky for both the contamination cloud brightness and for the night sky (S073) experiments. The background brightness is the measure of the total number density of scatterers along the line of sight.

Data Return

Data requirements for photometer include pointing and stability information. Main mode of photometer and QCM data is electronic and the sample array will be returned in a vacuum container for postflight analysis.

APPENDIX XI

Thermal Control Coatings, Experiment M415

Principal Investigator: Harry Thayer, MSFC

Development Center: MSFC

Integration Center: MSFC

Contractor: None

Objectives

Experiment M415 will determine the degradation effects of pre-launch, launch, and space environments on the thermal absorption and emission characteristics of various coatings commonly used for passive thermal control.

Background

The easiest, simplest, and often least expensive way to control spacecraft temperatures is by matching the thermal-radiative properties of exposed surfaces to their space thermal environments. Although many thermal control coatings exist with a wide range of absorption and emission properties, the pre-launch, launch, and space environments often alter these properties and eliminate or seriously diminish this mode of thermal control. In addition, since the degree to which the surfaces are altered cannot be predicted accurately, the other thermal control elements must be oversized to insure adequate temperature control in space.

A number of ground based simulation tests have been performed, but they have not considered simultaneously the full range of conditions affecting coating properties. Experiment M415 is the first attempt to measure the effects of these conditions during the various stages of an actual launch and thus will provide a good correlation for the ground based tests. Experiment M415 along with Experiment D024, which covers the effects of space residence only, should clear up some of the mysteries associated with changing coating properties and thus permit more precise thermal control design.

Hardware

The principal elements of this experiment consist of two identical panels, each containing 12 thermal sensors arranged in four rows of three. Three different thermal control coating samples are mounted on the sensors in each row, with each column containing the same sample material. This arrangement allows the samples to be exposed to four different conditions in identical sets of three per exposure. Three of the four sets of test samples on each panel are protected with covers attached by armament thrusters. The remaining set is protected by a bolt-on cover which will be removed prior to launch. In order to provide a worst-case baseline for data correlation, one sample on each panel is covered with a black, totally absorbing paint.

Protocol

One set of sample coatings will be exposed to all environments. A second set will be exposed immediately prior to Launch Escape System tower jettison and all environmental conditions thereafter. The third series will be exposed to retrorocket firing and space environment, while the fourth series will be exposed to space environment only. The test specimens will be located at two positions on the Instrument Unit (IU) to provide two degrees of exposure to retrorocket firing. Aerodynamic fairings will be provided to assure a laminar flow stream for the test specimens during launch ascent.

The experiment will utilize the power, functional command, attitude control and data handling capabilities of the IU. Crew participation is not required for any phase of the experiment.

Data Return

All of the coating samples are thermally isolated from surrounding structures, therefore average thermal-radiative properties can be easily calculated from telemetered temperature measurements. These calculated values will then indicate how the various environments altered coating characteristics. Unlike Experiment D024, detailed spectral reflection measurements cannot be made since the coatings will not be retrieved.

APPENDIX XII

Thermal Control Coatings, Experiment D024

Principal Investigator: Carl P. Boebel, Air Force Materials Laboratory, Wright Patterson AFB

Development Center: Wright Patterson AFB

Integration Center: MSFC

Contractor: None

Objectives

This experiment, consisting of exposing material samples to the space environment, has the following objectives:

1. Determine the effects of near earth space environments on selected experimental thermal control coatings which have been extensively investigated in the laboratory;

2. Correlate the effects of the space environment on these selected coatings with measured effects of ground-based simulated space environments; and,

3. Gain new understanding of the mechanisms of degradation of thermal control coatings caused by actual space radiation.

Background

On all of our manned spacecraft and on many of our unmanned spacecraft, weight and power penalties can be attributed directly to the degradation of thermal control coatings. Such degradation alters the thermal-radiative characteristics of exposed surfaces. The designer must allow for these changes by oversizing thermal control components, and it is often the more complicated and expensive systems, such as radiator loops, that are affected. Due to the relatively short duration of the Mercury, Gemini, and Apollo missions, this has been only a minor problem. But for future, long duration manned missions, coating stability is critical.

Experiment D024 measures degradation that occurs only during the space residence phase of a mission. (Experiment M415 primarily measures launch and pre-launch effects.) White coatings are the most susceptible. These coatings normally absorb relatively little solar radiation but are very good emitters of energy. Therefore, they are often applied to areas that must be kept cool. However, when fully degraded, their ability to absorb solar energy doubles.

Many earth based experiments have been performed to measure such degradation. Unfortunately, telemetered data from unmanned spacecraft indicate degradation in space is more severe than is predicted by these tests. Explanations exist, but samples from space are needed to establish the exact causes. The Apollo 9 astronauts retrieved some samples. However, these samples were not protected from the cabin atmosphere after retrieval and their properties were certainly altered.

Experiment D024 will provide the first opportunity to examine in detail coating samples that have been chemically or physically unaltered since retrieval from space. At a minimum, test results will enable a better prediction of how currently available coatings degrade in space. An optimistic hope is that something can be learned to help develop newer, better coatings. In either case, the benefits for future missions are substantial.

Hardware

The experiment package consists of two panels, each containing 36 thermal control coating samples. The samples are one-inch diameter discs coated with various selected thermal control coatings. The panels are square plates, approximately 6-1/2 inches on a side and 1/4 inch thick. Each has a flexible handle to prevent contamination of the samples while handling.

Both panels will be attached with snap fasteners to the Airlock Module truss assembly located directly under the sun. In this position they will receive no cluster shadowing in the solar inertial attitude held during most of the mission. The panels will be protected with covers, which will be removed no later than 24 hours before launch. Since the Airlock Module will be protected by the payload shroud during launch, the samples will not be affected by the launch environment.

Protocol

One of the thermal control sample panels will be retrieved and returned to earth on Skylab flight SL-2 and the other panel will be retrieved and returned on flight SL-3. The first sample panel will be exposed to the space environment approximately 1 month, depending on the exact launch time and flight schedule, and the second sample panel will be exposed approximately 5 months.

During an EVA two astronauts will participate in the sample panel retrieval. One will photograph the operation, and the other will retrieve the panel and place it in a return sample container before re-entering the Skylab cabin environment. This hermetically sealed container will maintain a vacuum for the samples until they reach a ground-based laboratory where they will be placed in a vacuum chamber and a vacuum established before removal. Spectral reflection and all other measurements will be made in the chamber.

APPENDIX XIII

Expandable Airlock Technology (B), Experiment D021

Principal Investigator: F. W. Forbes, Space Technology Branch
Air Force Aero Propulsion Laboratory
Wright Patterson AFB

Development Center: Wright Patterson AFB

Integration Center: MSFC

Contractor: Goodyear Aerospace Corporation

Objectives

The objective of this experiment is to evaluate typical composite materials proposed for use in expandable structures under conditions of long-term space exposure.

Background

Air Force in-house and contractural research and development in the area of expandable structures dates back to 1960 and provides a firm foundation for the proposed experiment. Ground testing has progressed from initial materials tests through vacuum chamber testing of complete structural units. The next step in the development of expandable structure technology is the evaluation of structural materials after long-term exposure in orbit.

The experiment has potential value in the development of future space hardware, such as expandable crew airlocks and lunar shelters.

Hardware

Two sample panel mounting plates are installed on the AM support structure. The panels and plates are 6 x 6 x 1.4 inch assemblies containing a 6 x 6 x 1 inch section of expandable structure material. The composite material is constructed in layers, composed of the following (listed in order of inside to outside surfaces): aluminum (.35 mils), a gas barrier of two Nylon film and fabric surfaces enclosing EPT (Ethylene Propylene Terpolymer) foam, structural windings of stainless steel wire, a Polyurethane foam micrometeorite barrier, and a Nylon fabric outer surface with appropriate coatings for passive thermal control.

The experiment hardware also includes two sample return containers, which are mounted on the AM support structure. Each container provides compartments for one D021 and one D024 sample panel.

Protocol

The two D021 sample panels will be observed, photographed, and retrieved by astronauts during two extra vehicular activities when ATM film and D024 samples are also retrieved. The first panel will be retrieved at the end of the first manned mission after an exposure of approximately one month and returned to earth by the CSM SL-2. The second sample will be retrieved after approximately five months exposure and returned by CSM SL-3.

The D021 and D024 sample panels will be placed in a D021 sample return container on each EVA, and the containers will be sealed so that the samples remain in a vacuum environment until they reach a ground-based laboratory.

Date Return

The sample panels will be photographed by a 70-mm still camera before retrieval by an EVA astronaut. A second EVA astronaut will record the retrieval operation on movie film. The samples themselves constitute the primary return from orbit to earth. Ground based observations will provide data on the effect of orbital exposure on the materials tested.

APPENDIX XIV

Materials Processing in Space, Experiment M512

Principal Investigator: P. G. Parks, MSFC

Development Center: MSFC

Integration Center: MSFC

Contractors: Westinghouse Electric (Crystal Growth and electron beam gun)

Arthur D. Little (design of Sphere Forming Experiment)

Objectives

Molten metal flow, freezing patterns, thermal stirring, fusion across gaps and surface tension are presently known only as gravitational phenomena. The objective of this experiment is to demonstrate and evaluate the merits of these molten phenomena for manufacturing in a space environment. Molten metal flow characteristics will be studied and evaluated under zero gravity and space vacuum conditions. There are five parts to the experiment:

1. Metals Melting Task: The purpose of this task is to examine the molten metal flow characteristics of various metal alloys.

2. Sphere Forming Task: The purpose of this task is to fabricate spherical shapes during orbit by taking advantage of the virtual absence of a gravitational field.

3. Exothermic Heating Task: The purpose of this task is to develop a stainless steel tube joining technique for assembly and repair in space, to study and evaluate the flow and capillary action of molten braze material, and to demonstrate the applicability of exothermic reaction in space.

4. Composite Casting Task: The purpose of this task is to determine if the metallurgical structure of composite aluminum materials is improved by casting these materials in space.

5. Growth of Single Crystals Task: The purpose of this task is to attempt to grow single crystals of gallium arsenide.

Background

In this experiment, fundamental research on the effects of near-zero gravity and space vacuum on molten metal phenomena will be conducted. There are two possible applications of this basic research:

1. the development of a capability to manufacture useful products in space that cannot be made on earth or products which are available on earth but which can be made more economically in space, and

2. the development of in-space techniques for construction, assembly, and maintenance of space structures to be used in future space missions.

The Apollo program will have some limited, predecessor demonstrations of some of the phenomena expected to apply to these processes, but they will not return the necessary, parametric information that this experiment should supply.

The five processes proposed for investigation have already been mentioned. Some of the ways in which space performance is expected to affect them are explained below.

The melting of materials is a phenomenon common to all of the tasks. This requires the application of heat. On earth, temperature differences cause density differences, which cause convection under the influence of gravity. Convection may or may not be a hindrance, depending on the objectives of the process. In space it would be much easier to control convection.

In certain processes of material preparation, contamination is a problem which space manufacture may avoid. There are some products which require such high degrees of purity that the most inert supporting containers would still contaminate the product by contact. On earth, conducting materials can be levitated (removed from contact with supporting material by application of an RF field), but only in small quantities. Nonconductors cannot. In space it may be possible to process both these materials without poisoning, since suspension is natural in zero gravity.

Another effect of gravity which space processing can avoid is the separation of different density materials in the preparation of composites. Certain materials of superior characteristics might be formed if a uniform or other preferred mixture of substances of different density could be attained. On earth the desired embedded fibers or particles either float or settle, but in space this could be avoided.

While the presence of vacuum in space is not nearly so significant as the very low gravity to material processes, the ready availability and easy maintenance of high vacuum is very useful.

Hardware

The experiment equipment consists of two basic parts, a Materials Processing Facility and the Specimen Containers. The Materials Processing Facility is used as the device in which the five experiment tasks and Experiment M479 (Zero Gravity Flammability) are performed. The Specimen Containers house the various test samples, and one container is used for returning samples.

The Materials Processing Facility is hardmounted in the MDA. It consists of a battery powered electron beam generating device, a control panel, and a vacuum work chamber. The experiment task samples are placed in the vacuum work chamber where either vehicle power, exothermic devices or the electron beam gun can be used as a heat generating source. The Specimen Containers are used to house the various samples for the five experiment tasks and also the various other items of experiment hardware. Specifics on the experiment specimens are given in the next section on operations.

Protocol

The crew is a necessary part of this experiment. They must install all samples and specialized hardware for each task in the vacuum work chamber, perform the task from the control panel, record their observations and photograph the phenomena, and remove and package the samples. Specific operations for the five tasks are:

1. Metals Melting Task: Three sample discs consisting of four metal specimens of different thickness and alloy will be automatically rotated at a controlled speed under the electron beam gun and the molten metal flow characteristics will be observed and photographed. The samples will be returned.

2. Sphere Forming Task: Twenty-eight 0.25 inch diameter spherical specimens will be cast using the electron beam gun as a heating source. Forming operation will be observed and photographed and spherical samples returned.

3. Exothermic Heating Task: Five 0.75 inch diameter tubes will be joined using a silver-copper-lithium braze alloy. The five tubes are packaged in one array. The heat source to perform

this braze will consist of a mixture of powders which combine chemically to give off heat when triggered by an electric current.

4. Composite Casting Task: Three composite materials will be fabricated in space by unidirectional solidification of aluminum alloys containing silicon carbide fibers. After solidification, the specimens will be compared with those cast on earth to determine improvements of the metallurgical structure.

5. Growth of Single Crystals Task: Three samples will be packaged in a single furnace heating package. During performance of the experiment the furnace will heat and cool the samples in a controlled manner to attempt to form single crystals of gallium arsenide.

All five tasks of this experiment will be completed in the vacuum chamber of the Materials Processing Facility prior to the performance of Experiment M479 (Zero Gravity Flammability).

The returned metal samples will be studied and evaluated, both independently and by comparison to samples obtained in a unit earth gravity environment. The photographic data will be reviewed and compared to subjective data recorded in the astronaut logs and voice records.

Data Return

The processed samples from all tasks will be returned. Besides the specimens, data will consist of photographs taken by the 24 frame per second data acquisition camera and astronaut comments recorded on tape and in the experiment log book.

APPENDIX XV

Zero Gravity Flammability, Experiment M479

Principal Investigator: J. H. Kimzey, MSC

Development Center: MSFC

Integration Center: MSFC

Contractor: None

Objectives

Ignite various materials in a 5 psia oxygen/nitrogen mixture to determine: (a) extent of surface flame propagation, flashover to adjacent materials; (b) rates of surface and bulk flame propagation under zero convection; (c) self-extinguishment; (d) extinguishment by vacuum or water spray.

Background

Previous studies of flame propagation under conditions of zero gravity were done in aircraft. Self-extinguishment was observed but the flame reappeared when convection resumed at the end of weightlessness. Longer test times are required so that more information can be made available on the ignition, propagation, and extinguishment characteristics of various non-metallic materials under space environments so that the design of future manned space vehicles will provide maximum crew safety and reliability.

There are also some fundamental scientific benefits to be gained from a study of combustion in a low gravity environment.* While M479 is not intended to furnish data of this sort, it will serve as a baseline for design of later experiments. In low gravity fields, the buoyant motions that usually dominate the combustion process are greatly diminished. This will permit the study of the other steps in the process, such as reactant gas diffusion, that are usually masked by the convective effects.

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*Although the gravitational force is severely reduced, true zero gravity is not attained on the Skylab. In an analogous situation on the Apollo CSM, a gravitational force of 10^{-7} "g" has a significant effect on heat transfer in the cryogenic oxygen tanks.

Further, the differential equations describing the governing transfer processes are much more susceptible to solution in the absence of the convective terms. Thus, the low gravity environment offers a unique viewpoint for observing the combustion process.

Hardware

The combustion chamber and controls for this experiment are provided by Experiment M512. The combustion chamber is stainless steel with a low emissivity interior; it is part of the M512 Materials Melting Facility. A large opening on one end enables igniter-fuel assemblies to be installed. Two glass ports are provided for viewing by the operator and cameras. The camera lens, mounting brackets, and power/control cable are furnished by Experiment M512. Chamber connections are provided for venting to vacuum to get rid of smoke and products of combustion, venting to the vehicle interior to equalize pressure and to permit opening. Interior work lights are provided, as well as means to remove solid ash particles by a "vacuum cleaner" equipped with a filter trap. Provisions are also made to add water spray to evaluate extinguishment by that means. A storage container for water at low pressure is supplied as part of the Materials Melting Facility. The igniter-fuel assemblies are housed in a separate container which serves both as environmental protection to the assemblies and as a place to dispose of used assemblies after testing.

Protocol

Initial operation of M479 shall be attempted only after all phases of M512 are completed. The experiment operator can perform all functions from a single location. The preparation to test involves carrying water, a camera and sufficient film to the test location. After checking electrical and mechanical equipment no outside involvement is needed as long as electrical power, oxygen and vacuum are maintained. Operation involves manually operating valves, latches, and electrical controls in accordance with a check list. Between tests the operator has to remove used specimens, install new specimens, clean chamber interior with a vacuum cleaner and cloth, and change camera film as required.

A series of 37 tests will be performed. Each test will be conducted in the Skylab oxygen/nitrogen atmosphere mixture at 5 psia, nominally. The mylar, nylon, polyurethane, cellulose paper, and Teflon samples will be electrically ignited. Some tests will involve ignition of the test material and observation of the progress of combustion. There will also be tests to observe the effects of dumping of the chamber atmosphere and the addition of a water spray. Materials will be ignited at distances of 1/2, 1/4, and 1/8" from identical unignited samples to determine minimum distances without igniting the second sample. Materials will also be ignited and then detached from the igniter.

Data Return

Motion picture coverage of ignition and flame propagation will serve as the primary record of data. Color film coverage at 24 frames per second is required for all but one test series in which infrared film will be used. Individual flammability tests last a minimum of ten seconds to a maximum of four minutes. Each test will be photographed in its entirety so that combustion rates can be determined by post-flight analysis.

Additional data will be available from the voice comments of the astronaut performing the experiment. The astronaut will be invaluable in observing several aspects of the tests that may be missed by photography. He should be better able to note drift rates of detached fuel specimens, heat loads to the chamber walls, ash scatter, condensation, and sublimation products and overall energy profiles as well as trouble-shoot malfunctions of igniters, cameras, etc., and report environmental changes exterior to the combustion chamber. Water spray patterns can also be reported. This voice information shall be adequately detailed so that, in being broadcast to the ground, the PI will be able to answer questions that arise and help decide whether procedural modifications are necessary.

APPENDIX XVI

Precision Optical Tracking, Experiment T018

Principal Investigators: C. Wyman and J. Gould, MSFC

Development Center: MSFC

Integration Center: MSFC

Contractor: None

Objectives

Confirm and demonstrate the ability of a laser tracking system to accurately measure the position and motion of a space vehicle booster during the early launch phase.

Background

This experiment was in an advanced state of definition as early as 1964. At that time lasers were literally a solution looking for a problem. Had it been possible to implement this experiment as originally requested, it could have been one of the first applications of lasers. Now it will serve more to promote, in conjunction with other space related laser activities (such as already-implemented satellite tracking and lunar ranging, and soon-to-be-performed altitude measurement from lunar orbiting spacecraft and deep space communications), the development of laser instrumentation and operating techniques for application in the space program wherever appropriate and as they both mature. In particular, it should provide the confidence and experience necessary for the construction of an operational laser tracking system, which, with the expected capabilities, could increase range safety through improved impact point prediction.

Hardware

There are two essential, physically unconnected sets of equipment necessary for this experiment. The first is a five-cube-corner retroreflector, mounted beneath a protective fairing on the Instrument Unit (IU). Two of these, 180° apart, are the only experiment related equipment carried by the space vehicles. Together they weigh no more than 30 lbs., are completely passive, and make no requirements on the vehicles for other than mechanical support. The other set of experiment equipment is the ground-based laser, its pedestal, housing dome, and supporting instrumentation trailer. The gas laser emits a 35 milliwatt, continuous beam in a 1/3 milliradian (80 arc sec) angle. The laser is situated three kilometers from the launch site and irradiates the launch vehicle with a 1 meter diameter spot of light.

Protocol

The astronauts have no role in the performance of this experiment. Technicians uncover the retroreflectors as close to launch time as possible, the laser ground crew performs last minute checks and calibrations, and for the first 50 seconds of the launch the laser system automatically tracks the launch vehicle, generating information as to range, azimuth, elevation, and the rates at which these parameters are changing.

The experiment is conducted on three launches of the Skylab program.

Data Return

The first-line data return will be that of the laser system itself. Modulating the amplitude of the laser output at frequencies of 30 kilohertz, 1 megahertz, and 30 megahertz should avoid range ambiguity up to the maximum range of 10 kilometers and provide 1 centimeter resolution and 10 centimeter accuracy. Other expected measurements are: angle, to 5.0 seconds of arc accuracy; range rate, to 200 meters per second; angular rate, to 5 degrees per second; and angular acceleration to 1 degree per second.

Supporting data requirements are of two types. Pitch, yaw, and roll information during the first minute after liftoff must be made available for post flight analysis of the laser's performance. This information is telemetered back from the IU as part of the guidance data. Also, timing information of various types and accuracies is required during the experiment for synchronization functions.